Oregon Forest Carbon Policy

Scientific and technical brief to guide legislative intervention

Center for
Sustainable
Economy
Analysis • Solutions • Advocacy

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I. Summary

- ✓ Timber harvesting is by far the largest source of greenhouse gas (GHG) emissions in Oregon. Since 2000, annual emissions associated with removal of stored carbon, sacrificed sequestration, and decay of logging residuals averaged 33 million metric tons carbon dioxide equivalent (mmt CO2-e). Nationwide, logging emits more carbon than the residential and commercial sectors combined.

- ✓ Yet in Oregon, across the US, and globally, timber harvest emissions are not reported or proposed for regulation because of a "carbon flux" accounting system developed by the timber industry that, in essence, grants an automatic offset for carbon sequestered by tree plantations managed in accordance with baseline legal requirements. No other sector is able to escape emissions reporting in this way.

- ✓ But sequestration by timber plantations and management in accordance with minimum requirements of Oregon's Forest Practices Act (OFPA) cannot meet two of the most basic tests for the validity of offsets: additionality and permanence.

- ✓ The additionality test cannot be met because where tree plantations have replaced natural forests all that has changed is a big increase in emissions with no corresponding increase in sequestration and storage capacity. Nothing has been added to nature's background rate of sequestration. Moreover, reforestation is the existing law, so there is nothing additional that it contributes. The permanence test cannot be met because tree plantations are simply emissions in waiting, released on increasingly short rotations. Because of this, timber harvest emissions should be reported and regulated on par with other sectors.

- ✓ Lack of ecological standards for state and private forestlands has resulted in a landscape dominated by short rotation timber plantations that store far less carbon than natural forests.

- ✓ These plantations also undermine climate resiliency because they are much more susceptible to drought, disease, wildfire, floods, landslides, low summertime streamflow, thermal pollution, fish kills, regeneration failures, exotic and invasive species and other climate change-induced impacts than natural forests.

- ✓ The lack of regulation has also resulted in a rapid increase in carbon sequestration "dead zones" – recently clearcut lands that emit more carbon than they absorb. Statewide, there has been a net loss of 1.7 million acres of forest cover since 2000 and much of this is due to a rapid rate of clearcutting.

- ✓ Cap and invest, forest carbon tax and reward, and an Oregon Forest Resiliency Act (OFRA) with a climate test for proposed logging operations are three workable legislative options to remedy this situation, incentivize climate smart forest practices, generate thousands of new jobs and vastly improve climate resilience.

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Content:

II. Key facts to guide legislative intervention

1. Timber harvesting is the single largest source of greenhouse gas emissions in Oregon taking into account (1) stored carbon removed from site and lost in the wood products manufacturing process and subsequent decay of final products; (2) the lost sequestration capacity of clearcut lands and logging roads, and; (3) emissions associated with decay of logging debris.

Timber harvest activities generate emissions associated with the loss of carbon stored on site, the foregone sequestration of clearcut lands, the decay and combustion of logging residuals (slash) left behind after harvest, application of chemical herbicides, pesticides and fertilizers, soil disturbance, transportation, and operation of equipment.

For this analysis, timber harvest emission calculations were limited to the first three sources since data on the amount, types, and frequency of chemical and fertilizer applications are lacking and since equipment and transportation emissions are generally assigned to other sectors (i.e. transportation and industrial processes) in existing greenhouse gas (GHG) inventory methods. Emissions from soil disturbance are also difficult to quantify at this time. So, for purposes of this analysis, timber harvest related emissions are calculated as follows:

ETH = (REM – STOR) + FS + DR, where

ETH = timber harvest related emissions (million metric tons CO2-e per year)
REM = CO2-e removed from site by timber harvest
STOR = CO2-e removed from site and stored in long-lived (100+ years) wood products
FS = Foregone sequestration from recently clearcut lands
DR = Decay and combustion of logging residuals

Timber harvest removals (REM)

The amount of forest carbon stored on site and removed by timber harvesting is reliably measured by multiple forest carbon monitoring platforms. The most ubiquitous is the Forest Inventory and Analysis (FIA) database managed by the USDA Forest Service. According to the most recent FIA data for Oregon, REM has averaged 34.75 mmt CO2-e per year between 2000 and 2015 (Appendix A).[1] An analysis by CSE, Oregon Wild, and Geos Institute generally corroborated the FIA data by combining forest carbon stock data from Woods Hole Research Center with forest cover loss (timber harvest related) satellite derived data from University of Maryland and World Resources Institute.[2] The CSE analysis found the value of REM on state and private lands in western Oregon to average 23.21 mmt CO2-e per year between 2000 and 2014, just slightly above the FIA estimates (23.16 mmt CO2-e) for that region (Appendix B).

Carbon stored in long-lived wood products (STOR)

Forest carbon removed from site during timber harvest has one of two ultimate fates over a 100-year period:[3] (1) through biomass combustion and decay of waste or wood products, it ends up in the atmosphere, or (2) a portion of it survives intact in long lived wood products like structural lumber or furniture or remains buried in landfills. STOR estimates the second. In a nationwide analysis, Ingerson (2009) estimated STOR to range from zero to 21% of REM depending upon assumptions about the disposition of harvested wood (Appendix C).[4] Forest Service data tables for the Pacific Northwest estimate that 40.9% of the embodied carbon in sawlogs is retained after 100 years in longer lived wood products and landfills and 7.6% of the

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[1] USDA Forest Service. 2016. Forest Inventory and Analysis (FIA) data for Oregon. Table 2A: Growth, removals, and mortality of CO2 equivalent, by ecoregion and owner class. Attached as Appendix A.

[2] Talberth, J., DellaSala, D., Fernandez, E. 2015. Clearcutting Our Carbon Accounts: How State and private forest practices are subverting Oregon's climate agenda. Lake Oswego, OR: Center or Sustainable Economy and Geos Institute. Page 56, attached as Appendix B.

[3] The 100-year framework is standard for GHG accounting in the US and for forest carbon offset projects. Generally, offset projects need to ensure that storage is guaranteed for at least this long. See, e.g. Ecotrust: A Landowner's Guide to Carbon Offsets (http://archive.ecotrust.org/forests/fco_intro.html).

[4] Ingerson, A., 2009 Wood Products and Carbon Storage: Can Increased Production Help Solve the Climate Crisis? Washington, DC: The Wilderness Society.

embodied carbon in pulpwood is retained 100 years after harvest in short lived wood products and landfills (Appendix D).[5]

A 2016 analysis found that about 52% of Oregon's timber harvest ends up as longer-lived wood products in the form of finished dry lumber, other sawn products, finished plywood or veneer, 41% to short-lived products and 7% to waste and shrinkage (Appendix E).[6] This suggests a weighted average value of STOR of (52% x 41%) + (41% x 7.6%) + (7% x 0%) =24.44%, largely corroborating Ingerson (2009). In its initial (2009) analysis of forest carbon issues, the Oregon Global Warming Commission assumed a value of 25% for STOR, which is adopted here as a placeholder pending more detailed review of the current disposition of Oregon's harvested timber (Appendix F).[7]

Foregone sequestration from clearcut units (FS)

When timber is harvested from a site, sequestration is reduced or eliminated until a new stand is established. All other factors held constant, the atmosphere will experience an increase in CO2 concentration merely because the carbon dioxide once removed from the atmosphere by forest carbon sequestration at the site of harvest no longer occurs. FS measures this indirect emission. Measuring FS is a standard technique for evaluating the carbon costs of land conversion, including conversion of natural forests to short rotation biofuel crops (Appendix G).[8] Consideration of foregone emissions and the loss of associated economic benefits is also consistent with federal guidelines for economic analysis, which require use of a "with and without" framework. In particular, for an analysis of a proposed federal action, including a federal logging project, the guidelines require consideration of the stream of sequestration benefits that would have occurred in its absence.[9]

Research has demonstrated that in western Oregon, where even-aged (clearcut) techniques prevail, sequestration capacity is eliminated for 13 years after harvest. In particular, net ecosystem productivity (NEP) – sequestration by young seedlings and brush minus emissions from decay and combustion of logging residuals – is negative for 13 years after clearcutting, meaning that these lands are not only carbon sequestration dead zones but net emissions

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[5] Smith, J.E., Heath, L.S., Skog, K.E., Birdsey, R.A., 2006. Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States. Gen Tech. Rpt. NE-343. Morgantown, WV: USDA Forest Service, Northeastern Research Station.

[6] Simmons, E.A., Scudder, M.G., Morgan, T.A., Berg, E.C., Christensen, G.A. 2016. Oregon's Forest Products Industry and Timber Harvest 2013 With Trends Through 2014. Gen. Tech. Rpt. PNW-GTR-942. Portland, OR: USDA Forest Service Pacific Northwest Research Station.

[7] Kelly, P., 2009. A Greenhouse Gas Inventory of Oregon's Forests. Salem, OR: Oregon Global Warming Commission, Oregon Department of Energy.

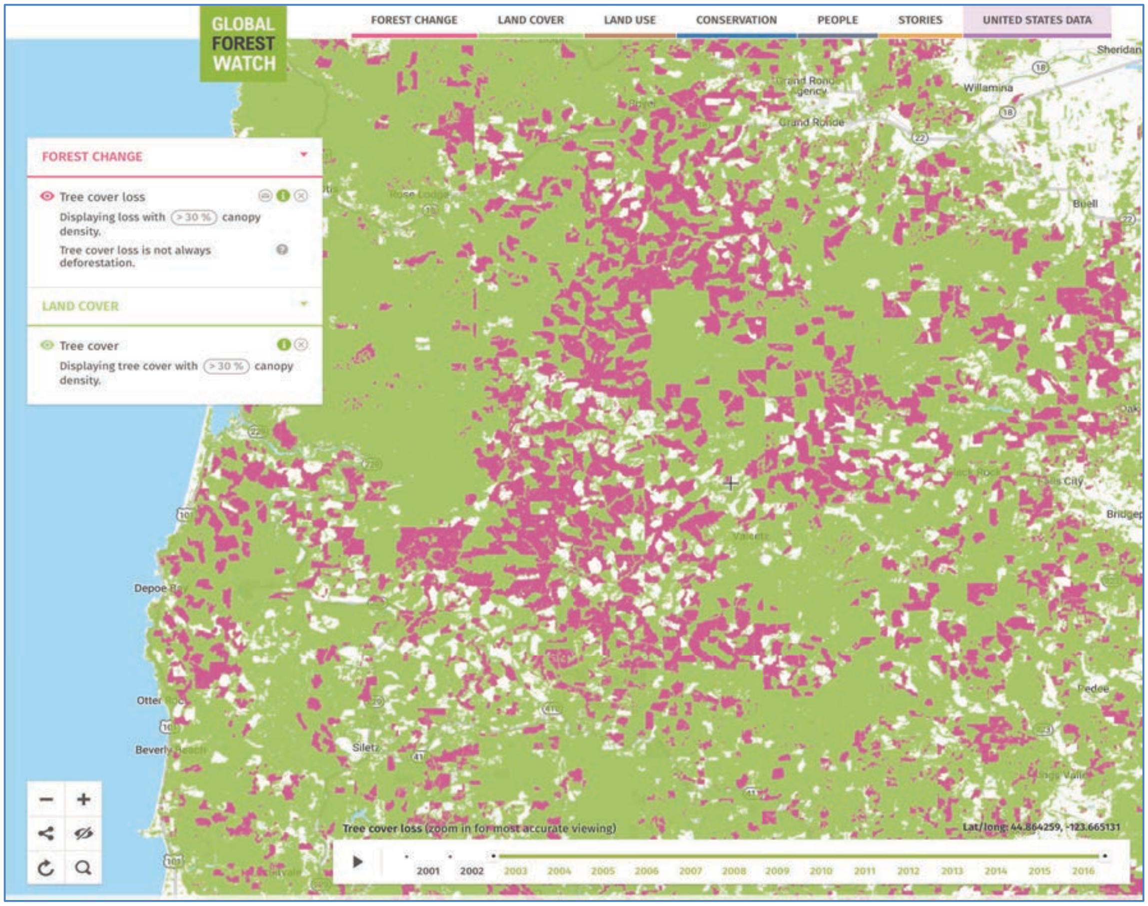
[8] Air Resources Board. 2014. Staff Report: Initial Statement of Reasons for Proposed Rulemaking. Appendix I, Detailed Analysis for Indirect Land Use Change. Sacramento, CA: California Environmental Protection Agency.

[9] Circular A-4 requires an analytical framework of with and without. Regulatory actions should be evaluated "by determining the net benefits of the proposed regulation with and without it." Circular A-4, Section E(3).

sources (Appendix H).[10] FS is simply the pre-harvest sequestration value multiplied by 13. Both the FIA data and the NEP data agree on a mean sequestration value for western Oregon state and private forestlands – 4.74 tCO2-e per acre per year. So total FS associated with a typical clearcut unit in western Oregon is 4.74 x 13 or, 61.62 tCO2-e per acre.

Satellite data can be used to estimate the amount of land clearcut each year and the amount of land in the 0-13 age class post harvesting. World Resources Institute's Global Forest Watch project (GFW) provides a convenient and easy to access tool to do this. It measures forest cover loss and gain annually and allows users to select the canopy closure thresholds particular to the forest type they are analyzing. Using GFW, the CSE/Geos analysis estimated an annual average rate of clearcutting of 91,529 acres on state and private lands in western Oregon alone after filtering out other sources of forest loss, such as wildfires and urban development. Multiplying this by the per acre forgone sequestration value implies an FS figure of at least 5.64 mmt CO2-e/yr from these lands.

Figure 1: Sequestration dead zones 2016, central Coast Range, Oregon
(*Areas in red were clearcut within the last 13 years and emit more carbon than they sequester*)



Displaying loss with >30 % canopy density.

Tree cover loss is not always deforestation.

Displaying tree cover with >30 % canopy density.

Tree cover loss (zoom in for most accurate viewing)

Lat/long: 44.864259, -123.665131

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[10] Turner, D.P., Guzy, M., Lefsky, M.A., Ritts, W.D., Van Tuyl, S., Law, B.E., 2004. Monitoring forest carbon sequestration with remote sensing and carbon cycle monitoring. *Environmental Management* 33(4): 457-466.

At the end of the analysis period (2000-2014), acreage in the 0-13 post-harvest age class was estimated to be roughly 1.2 million acres. And this figure is growing. An increase in the areal extent of carbon sequestration dead zones occurs when forest cover loss outpaces forest cover gain. CSE and Oregon Wild documented a net loss of over 520,000 acres in western Oregon alone since 2000.[11] Due to this effect, large portions of the Coast Range are now dominated by these sequestration dead zones (Figure 1). Statewide, since 2000, net forest cover loss (forest cover loss minus forest cover gain) is estimated to be 1.7 million acres – meaning that, as seen from the air, Oregon has 1.7 million acres less forest cover than it did in 2000 (Appendix I). As such, carbon sequestration capacity is decreasing at a fairly rapid rate.

Decay and combustion of logging residuals (DR)

As indicated in Appendix H, newly clearcut lands are net emissions sources, not sinks, for 13 years after harvest, largely as a result of the decay of logging residuals – slash, stumps, wasted logs and dead roots – as well as their combustion when burned. The NEP data can be used to calculate these emissions. An average value for western Oregon (combining data for the Coast Range and West Cascades) is 1.1 tCO2-e per acre per year. The CSE/Geos analysis estimates that, presently, there are about 1.2 million acres on state and private lands in western Oregon alone in the 0-13 age class post-clearcut harvest. This implies a current annual DR value of at least 1.32 mmt CO2-e.

Total emissions related to timber harvest (ETH)

Combining emissions associated with timber harvest removals (REM), storage in long-lived wood products (STOR), foregone sequestration (FS), and decay and combustion of logging residuals (DR) suggests that emissions associated with timber harvest (ETH) averaged 33.03 mmt CO2-e per year between 2000 and 2015 (Figure 2). This is a minimum figure since it includes an optimistic figure (25% for RES) and only assigns forgone sequestration to a portion of the landscape affected by clearcutting. Putting this figure into perspective, it represents by far the largest source of emissions statewide (Figure 3). Across the US, and just counting REM minus STOR, timber harvest emissions are larger than emissions from the residential and commercial sectors combined.[12]

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[11] Talberth, J., Fernandez, E., 2015. Deforestation, Oregon Style. Lake Oswego, OR: Center for Sustainable Economy.

[12] Moomaw, B., Smith, D., 2017. The Great American Stand. US Forests and the Climate Emergency. Asheville, NC: The Dogwood Alliance.

Figure 2: Components of timber harvest related emissions in Oregon (2000-2015 average)

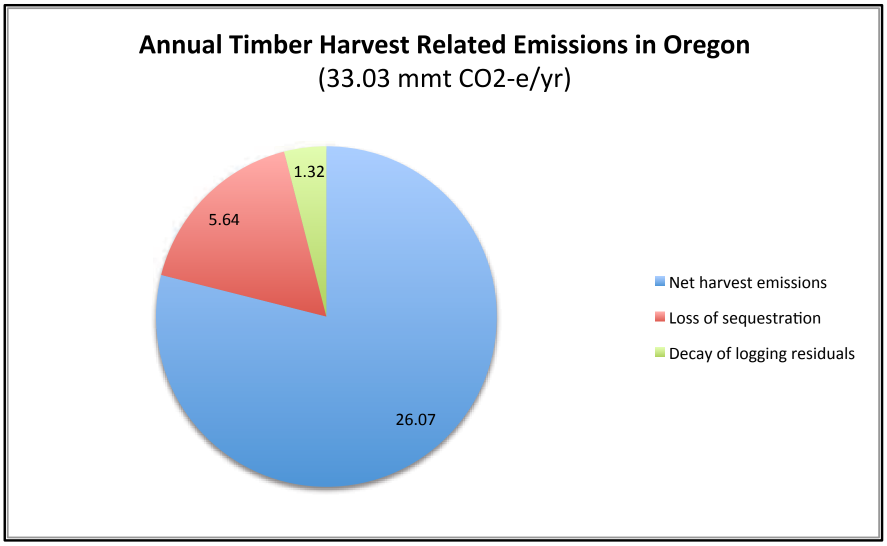
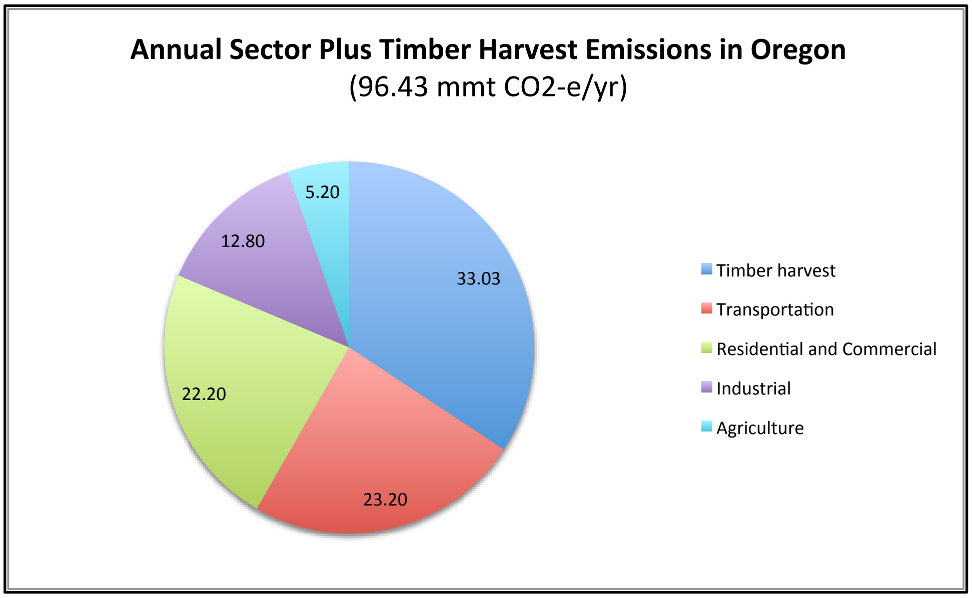


Figure 3: Timber harvest is by far the largest source of GHG emissions in Oregon each year



2. The timber industry has evaded responsibility for these emissions by developing a forest carbon accounting system that grants 100% offsets for carbon captured by short rotation timber plantations despite the lack of additionality or permanence associated with their management.

Given the complexities of forest carbon accounting international agencies allowed the timber industry to write its own rules. They were adopted as a subset of the GHG inventory rules for the broad Land Use, Land Use Change, and Forestry (LULUCF) sector adopted by the UN at COP 7 in Marrakesh in 2001. As noted by several NGOs who closely monitored the situation "[t]he rules agreed on LULUCF at COP7 in Marrakesh were designed largely by the forest industry and driven by Annex 1 Parties seeking to evade accounting for emissions in the agriculture, forestry and land use (AFOLU) sector and to reach their emissions targets more easily" (Appendix J).[13]

In the accounting rules, this is accomplished by a focus on carbon flux – the wrong policy metric – and by ignoring the potential to capture and store vastly more carbon on the land through improved practices. Carbon flux merely measures the ins and outs of carbon on the landscape year to year rather than what is being permanently stored relative to capacity. A Christmas tree farm or even a suburban lawn can be managed in a way to balance the ins and outs each year. In this way, the often-heard phrase "our forests capture more carbon than they emit" becomes a meaningless statement. However, the timber industry has been successful at making the argument that so long as ins and outs are balanced there are no net emissions to report and the sector need not be regulated.

And decision makers have fallen for that logic. The EPA has duly noted that "[i]n the United States overall, since 1990 land use, land-use change, and forestry activities have resulted in more removal of CO2 from the atmosphere than emissions. Because of this, the Land Use, Land-Use Change, and Forestry (LULUCF) sector in the United States is considered a net sink, rather than a source, of CO2 over this period."[14] The Oregon Global Warming Commission followed suit, with even more optimistic language in its Forestry Roadmap for 2020. It noted "Oregon's forests are a carbon sink, capturing more carbon than they release. As such, Oregon's forests and its forest sector have and will continue to contribute to the goal of achieving reductions in greenhouse gas emissions by remaining a robust and sustainable sector in Oregon."[15] As a metric to guide policy, the carbon flux approach is problematic for a number of reasons:

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[13] Global Witness, Wetlands International, Rainforest Action Network, The Wilderness Society. 2003. De-Constructing LULUCF and its Perversities. Published online at: www.ecosystemsclimate.org.

[14] US EPA. Sources of Greenhouse Gas Emissions. Land Use, Land Use Change, and Forestry Sector Emissions. Available online at: https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions#land-use-and-forestry.

[15] Oregon Global Warming Commission (OGWC). 2010. Interim Roadmap to 2020. Salem, OR: OGWC.

- Storage is more important. Forest carbon storage (carbon density) relative to natural capacity is a far more important and policy relevant metric. This metric tells us how much more carbon can be removed from the atmosphere and permanently stored in service of leveling out and then reducing global CO2 concentrations back to the 350 parts per million (ppm) safe zone.[16] A zero carbon flux policy objective (making sure that on average, over time, emissions are balanced by sequestration) supports business as usual "catch and release" forest practices while one that sets targets for storage supports climate smart "catch and store" practices that are vital on the path to 350 ppm.

- No additionality. The timber industry has done nothing to deserve an effective 100% offset for carbon captured by its short rotation timber plantations. Reforestation is the law. So is management by the crude standards of the Oregon Forest Practices Act. If that's all that's being done, then there is no additionality. As defined by Senate Bill 557 (2017), additionality means that offsets "[m]ust result in greenhouse gas emissions reductions or removals that are in addition to greenhouse gas emissions reductions or removals otherwise required by law..".[17] Additionality is also an illusion because long before the timber industry came along, forests blanketing the state were already sequestering carbon. Nothing has been added to nature's background rate of sequestration.

- Nor is there permanence. A key aspect of valid offsets is that they must store carbon for at least 100 years. Rotations are approaching 35 years or less. Whatever carbon is being sequestered in these tree plantations is merely being stockpiled for release relatively soon.

- Bad actors are hidden from view. Good actors and bad actors are lumped together in one big "forest sector" that allows bad actors to evade detection and be credited with sequestration that occurs on lands they do not own. In particular, bad actors with high emissions from clearcutting are able to mask their emissions behind the sequestration accomplished on national forests and other relatively well protected lands – lands, ironically, that they have fought hard against protecting. Regardless of whether or not the forest sector as a whole sequesters more carbon on balance that it releases, the reality is that within this sector there are high carbon emitters that need to be regulated and phased out in order to widen the gap between sequestration and emissions and thereby quicken the accumulation of carbon stored permanently on the land.

No other sector now regulated or proposed for regulation enjoys the advantages conferred by this carbon flux approach. Other sectors must adhere to a strict process for qualifying anything

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[16] Rockstrom, J., Steffen, W., Noone, K., et al., 2009. A safe operating space for humanity: identifying and quantifying planetary boundaries that must not be transgressed could help prevent human activities from causing unacceptable environmental change. *Nature* 461, 24 September 2009, available online at: https://www.nature.com/articles/461472a.

[17] SB 557, 2017 Oregon Legislative Assembly § Section 9(3)b(B).

they do as offsets against their emissions. Rules for other sectors do not permit major emission sources (bad actors) to invoke emissions reductions by others (good actors) as an excuse for ignoring the former. The other major sector that both emits and sequesters carbon – agriculture – is not governed by a carbon flux approach. Instead, agriculture emissions are reported as just that – emissions, without invoking any of the sequestration that may be associated with crops, riparian zones, idled farmland, cover crops or other best management practices. And while agricultural emissions are reported alongside other sectors in the OGWC's biennial reports, the timber industry's emissions are conspicuously absent.

3. If allowed to mature, Pacific Northwest forests can capture and store more carbon per acre than any other major forest type on the planet. Old growth forests in western Oregon can store over 1,000 tons CO2-e per acre.

The Intergovernmental Panel and Climate Change (IPCC) has produced carbon storage metrics for 13 forest biomes within four global forest types: tropical, subtropical, temperate, and boreal. Pacific Northwest forests are part of the cool temperate moist biome, which is the most carbon rich biome on Earth with mean storage of 233 tons carbon per hectare (tC/ha).[18] This biome "default" value, however, includes both cutover and old growth lands and various forest types. Old growth forests in the Pacific Northwest store far more. Forest carbon density in Oregon's ancient forests has been found to top 1,000 tC/ha. For example, throughout the H.J. Andrews Experimental Forests, Seidel et al. (2012) found mean carbon storage in old growth to be 724.5 tC/ha, with maximum values over 1,200 tC/ha. The mean value is equivalent to 1,076 tCO2-e per acre (Appendix N).[19]

4. Vast improvements in carbon storage can be achieved on all forestlands in Oregon. A modest increase of 25% to 66% depending on ownership class could increase storage by over 3 billion metric tons CO2-e, equivalent to 50 years of Oregon's fossil fuel-related emissions.

Current carbon stocks are just a fraction of what existed in ancient forests that once dominated the landscape, and modest storage improvements can have globally significant benefits. Appendix M presents data from the most recent FIA estimates of carbon density on Oregon forestlands prepared for the Oregon Global Warming Commission.[20] In western Oregon, carbon density across ownerships is closely related to how intensively these lands are managed from a timber supply standpoint. Simple mean densities for two sub-regions – the Coast Range and Western Cascades – is at its lowest (108 tC/ac) for private industrial lands and highest (157

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[18] Keith, H., MacKey, B.G., Lindenmayer, D.B., 2009. Re-evaluation of forest biome carbon stocks and lessons from the world's most carbon-dense forests. PNAS 106(28): 11635-11640).

[19] Seidl, R., Spies, T.A., Rammer, W., Steel, E.A., Pabst, R.J., Olsen, K., 2012. Multi-scale drivers of spatial variation in old-growth forest carbon density disentangled with Lidar and an Individual-Based Landscape Model. Ecosystems 15: 1321-1335.

[20] OGWC, 2016. Table 5. Estimates of carbon stocks in Oregon by pool type, from FIA data 2001-2010 (soil C modeled), by ecoregion section and owner group.

tC/ac) for national forest lands. This range is 34% to 49% of an old growth reference value of 320 tC/ac.

Modest improvements in carbon density through implementation of climate smart practices can have a globally significant impact. There has been no systematic evaluation of what can be attained at this time. However, a hypothetical scenario that improves carbon storage by 25% on private industrial lands, 33% for non-industrial lands, 50% on state lands, and 66% on national forest lands could capture and permanently store over 3 gigatons (3 GtCO2-e). This is equivalent to about 50 years of currently reported emissions associated with fossil fuel combustion in Oregon.

5. Carbon emissions and low carbon storage are not the only climate concerns. Landscapes dominated by industrial tree plantations also undermine climate resiliency by accelerating the extinction of species that need real forests to survive and migrate, by increasing water temperatures, by decreasing summertime water flow, decreasing long term site productivity and by increasing the incidence and severity of wildfires, insect outbreaks, disease, and landslides.

Large swaths of the forested landscape in western Oregon are dominated by tree plantations.[21] Plantations also exist east of the Cascades, but represent a smaller share. The extent of these plantations is not monitored because state law and state forest inventory data do not distinguish between these plantations and natural forests. However, about 13.4 million acres in western Oregon are not legally restricted from timber harvest and on the vast majority of this land base natural forests have long been replaced by replanted stands.[22] The most intensively managed plantations are found on the 4.2 million acres of industrial (corporate) forestland in western Oregon.

From a climate policy standpoint, failure to address the extent and spread of timber plantations is a major gap because these plantations pose a grave risk to native ecosystems and forest dependent communities as climate change unfolds. This is because these plantations are far more vulnerable to drought, disease, wildfire, floods, landslides, low dry season streamflow, thermal pollution, fish kills, regeneration failures, exotic and invasive species and other climate change-induced impacts than natural late successional forests and riparian vegetation. For example:

- Depleted water supplies. Dry season stream flows are today dramatically depleted on a widespread basis across western Oregon and the Pacific Northwest as a consequence

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[21] Franklin, J., Johnson, K., 2012. A restoration framework for federal forests in the Pacific Northwest. *Journal of Forestry* 110(8): 429-439.

[22] Bansal, S., Brodie, L., Stanton, S., Waddell, K., Palmer, M., Christensen, G., Kuegler, O., 2017. Oregon's Forest Resources, 2001-2010: Ten Year Forest Inventory and Analysis Report. Gen. Tech. Rpt. PNW-GTR-958. Portland, OR: USDA Forest Service Pacific Northwest Research Station.

of extensive logging and vegetative regrowth in plantations following logging (Perry and Jones, 2016).[23] Long-term paired watershed experiments indicate that the conversion of mature and old growth conifer forests to plantations of native Douglas fir produced persistent summer streamflow deficit of 50 percent relative to reference basins, in plantations aged 25 to 45 years (BLM, 2017).[24] Climate change will make matters worse by further reducing dry season flows thereby straining "the ability of existing infrastructure and operations to meet the many and varied water needs of Oregonians."[25]

- Water pollution. As the climate warms and dries in the summer, Oregon's waterways will also warm. This thermal pollution is made worse by plantation forestry. Department of Forestry modeling concludes that a typical clearcut compliant with the OFPA on average, boosts water temperatures by 2.6 degrees Fahrenheit over and above any background increase due to climate change.[26] According to multiple federal agencies, "the evidence is . . . overwhelming that forest practices on private lands in Oregon contribute to widespread stream temperature problems."[27] Warmer water, in turn, will cause "harmful algal blooms to occur more often, in more waterbodies and to be more intense."[28]

- Fish kills. Salmon, steelhead, and trout are among Oregon's coldwater dependent fish that are already harmed by higher water temperatures, sedimentation, and hydrological changes caused by industrial tree plantations. Climate change will accelerate the loss of fish habitat on these lands by increasing the frequency and severity of storms that deliver high sediment loads to streams and periods when high water temperatures become lethal.[29] In 2015, over a quarter million salmon were killed by warm water as they returned to the Columbia River and its tributaries.[30]

- Greater wildfire risk. Timber plantations burn hotter and faster than natural forests. This is because they lack the moisture content and structural complexity needed to keep

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[23] Perry, T. D., Jones, J.A., 2016. Summer streamflow deficits from regenerating Douglas-fir forest in the Pacific Northwest, USA. *Ecohydrology.* 1-13.

[24] Bureau of Land Management, 2017. Environmental Assessment and Draft Finding of No Significant Impact for the Pickett West Forest Management Project. Grants Pass, OR: USDI Bureau of Land Management Grants Pass Field Office.

[25] Dalton, M.M., K.D. Dello, L. Hawkins, P.W. Mote, and D.E. Rupp, 2017 *The Third Oregon Climate Assessment Report*, Oregon Climate Change Research Institute, College of Earth, Ocean and Atmospheric Sciences, Oregon State University, Corvallis, OR, page 18.

[26] Oregon Department of Forestry (ODF), 2015. Detailed analysis: predicted temperature change results. Agenda Item 7, Attachment 3 to the meeting packet prepared for the Board of Forestry, June 3rd, 2015. Salem, OR: ODF.

[27] EPA-FWS-NMFS, 2/28/01 Stream Temperature Sufficiency Analysis Letter to ODF and ODEQ.

[28] US Environmental Protection Agency, "Climate change and harmful algae blooms," available online at: https://www.epa.gov/nutrientpollution/climate-change-and-harmful-algal-blooms.

[29] Dalton et al., 2017, op. cit. note 23, page 25.

[30] Ridler, K., 2015. "Hot water kills half of Columbia River sockeye salmon." Associated Press, published online on Oregon Live at: http://www.oregonlive.com/environment/index.ssf/2015/07/hot_water_killing_half_of_colu.html.

wildfires in check. Decades of monitoring by firefighters and researchers have shown that fires that burn in complex natural forests create a mosaic of intensely burned and relatively untouched areas. Conversely, fires that burn in homogenous tree plantations are more likely to be uniformly severe.[31]

- **Landslides and flash floods**. The vast network of clearcuts and logging roads that permeate industrial timber plantations present a big risk for landslides, especially during extreme precipitation events such as the 1996 floods. Under almost all climate change scenarios for Oregon, the frequency of these events will increase. Maintenance of strong root systems is an important factor in stabilizing soils during these events. Clearcutting reduces the strength of these root systems dramatically, and thus is a major factor in increased landslide risk.[32] Logging roads channel water runoff and result in debris torrents that can travel many miles downstream, pick up momentum, and cause widespread destruction.[33] Studies indicate that clearcuts exhibit landslide rates up to 20 times higher than the background rate. Near logging roads, landslide rates are up to 300 times higher than forested areas.[34]

- **Invasive species**. Invasive species find few barriers in monoculture tree plantations since key natural processes that keep these species in check have been removed. As succinctly stated by Norse (1990) "in monocultures, without barriers to dispersal, insects and pathogens find unlimited resources in all directions."[35] As Oregon's climate changes, a wide variety of non-native plants, insects, and disease-causing organisms, such as viruses, bacteria, prions, fungi, protozoans, and internal (roundworms, tapeworms) and external (lice, ticks) parasites will spread, and adversely affect the health of humans, livestock, and pets in addition to fish and wildlife. For example, a recent Forest Service assessment concluded "[e]vidence suggests that future climate change will further increase the likelihood of invasion of forests and rangelands by nonnative plant species that do not normally occur there (invasive plants), and that the consequences of those invasions may be magnified."[36]

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[31] See, e.g. Stone, C., Hudak, A., Morgan, P., 2008. Forest harvest can increase subsequent forest fire severity. In Proceedings of the Second International Symposium on Fire Economics, Planning and Policy: A Global View. Armando González-Cabán, ed. Riverside, CA: USDA Forest Service, Pacific Southwest Research Station.

[32] Schmidt, K.M, J. J. Roering, J.D. Stock, W.E. Dietrich, D.R. Montgomery, Schaub, T. 2001. The variability of root cohesion as an influence on shallow landslide susceptibility in the Oregon Coast Range. *Can. Geotech. J* (38): 995-1024.

[33] Swanson, F. J., J. L. Clayton, W. F. Megahan, Bush, G., 1989. Erosional processes and long-term site productivity, pp. 67-81 in *Maintaining the Long-Term Productivity of Pacific Northwest Forest Ecosystems*. D. A. Perry, R. Meurisse, B. Thomas, R. Miller, J. Boyle, J. Means, C.R. Perry, R. F. Powers, eds. Portland, Oregon: Timber Press.

[34] Heiken, D., 2007. Landslides and Clearcuts: What Does the Science Really Say? Eugene, OR: Oregon Wild.

[35] Norse, E., 1990. Ancient Forests of the Pacific Northwest. Washington, DC: The Wilderness Society.

[36] Kerns, B., Guo, Q., 2012. Climate Change and Invasive Plants in Forests and Rangelands. U.S. Department of Agriculture, Forest Service, Climate Change Resource Center. Available online at: https://www.fs.usda.gov/ccrc/topics/climate-change-and-invasive-plants-forests-and-rangelands.

In addition to these risks, as climate change unfolds, the 1,100 or so species associated with late successional and old growth forests (LSOG) west of the Cascades need room to migrate – otherwise they are bottled up on federal lands where LSOG stands continue to be lost to logging and are threatened by climate change. To prevent these species from spiraling into extinction, timber harvest techniques need to change to halt and reverse the spread of biologically impoverished tree plantations and accelerate the development of LSOG conditions that could provide refugia for species displaced by adverse changes on federal lands.

6. Climate smart forest practices can significantly reduce emissions, enhance sequestration, build permanent storage, and increase climate resilience. These include forest carbon reserves, restoration of damaged and degraded land, alternatives to clearcutting, alternatives to chemicals and fertilizers, longer rotations, and various silvicultural practices that enhance sequestration of natural stands while building old growth characteristics.

The adverse effects of industrial forest practices on Oregon's climate agenda can be dramatically reduced by transforming these practices into climate smart alternatives. While the term 'climate smart' is a concept in need of further refinement it nonetheless is a useful one that can be applied to a number of specific practices that simultaneously reduce timber harvest emissions, increase permanent carbon storage on the land, and improve resiliency of the forested landscape. Rebuilding permanent carbon storage is key since it represents one of the few realistic pathways to reducing CO2 concentrations in the atmosphere back to the 350 ppm scientific safe zone. There are several general categories of climate smart practices that can accomplish these goals.

Forest carbon reserves

One obvious climate smart practice is setting aside all existing high-density forest carbon stocks as permanent reserves so that these stocks remain intact on the landscape rather than being released into the atmosphere through timber harvesting. Such high-density stocks – found mostly in late successional and old growth forests (LSOG) – make up a small fraction of the forested landscape in the Pacific Northwest. Within the range of the northern spotted owl, roughly 7% of the landscape exists in old growth forest condition, down from an historic distribution of between 30% and 70% at any one time.[37]

Most of the remaining endowment of LSOG forests on federal lands is administratively protected under existing management plans, however, loopholes in that protection coupled with increased pressure to reduce the extent of reserves by the Trump Administration is jeopardizing their status. On state and private lands, LSOG forests continue to be logged

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[37] Rapp, V., 2003. Science Update: New Findings About Old-Growth Forests. Portland, OR: USDA Forest Service, Pacific Northwest Research Station.

because there is very little protection under the Oregon Forest Practices Act or state forest practices laws in California or Washington. As a result, between 1994 and 2007, logging removed about 13% (491,000 acres) of what remains.[38]

Any climate policy designed to maintain and rebuild high density carbon stocks must halt any further loss and protect all remaining late successional and old growth forests from logging and other forms of anthropogenic disturbance. Forest carbon reserves should also include younger, highly productive forests that are likely to capture and store carbon rapidly while evolving into LSOG stands. Including forest carbon reserves in the portfolio of climate smart practices promoted under the state's climate agenda will help accomplish this goal.

Thinning dense tree plantations and other younger forests

Since carbon storage and resiliency to fires, drought, floods, and pathogens is maximized in LSOG forests, anything that can be done to put existing timber plantations and other younger forests on a trajectory to eventually develop LSOG conditions is smart climate policy. Importantly, this does not mean excluding timber harvest. To the contrary, in existing plantations and other younger forests it may require thinning in multiple entries over several decades to accomplish and thus provide a sustainable timber supply while rebuilding carbon stocks, improving climate resiliency, and enhancing other ecosystem services like water filtration and provision of fish, game, and non-timber forest products.

Over the past two decades, climate smart practices that accelerate the development of LSOG conditions from plantations have been field tested and verified, mostly on federal lands. For example, research in the Siuslaw National Forest has shown that thinning 30- to 35-year-old plantations to low densities and planting a mix of conifer seedlings can speed up development of old-growth characteristics in Douglas-fir forests.[39] There have been dozens of similar studies. Kerr (2012) provides a useful science synthesis on ecological restoration thinning techniques to accelerate the growth of large trees, create multiple canopy layers, increase understory plant diversity, and maintain deep crowns (branches growing well down the trunk). In moist forest plantations, he notes that "[t]he best available science concludes that [variable density thinning] VDT (leaving skips and gaps and using variable tree spacing, unlike an industrial thinning regime) can accelerate the onset of some characteristics of late-successional (mature and old growth) forests.[40]

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[38] Moeur,M., Ohmann J.L., Kennedy, R.E., Cohen, W.B., Gregory, M.J., Yang, Z., Roberts, H.M, Spies, T.A., Fiorella, M., 2011. Northwest Forest Plan, the First 15 Years (1994-2008). Status and Trends of Late-Successional and Old Growth Forests. Gen. Tech. Rpt. PNW-GTR-853. Portland, OR: USDA Forest Service Pacific Northwest Research Station.

[39] Chan, S.S., Larson, D.J., Maas-Hebner, K.G., Emmingham, W.H., Johnston, S.R., Mikowski, D.A., 2006. Overstory and understory development in thinned and underplanted Oregon Coast Range Douglas-fir stands. Can. J. For. Res. 36: 2696-2711.

[40] Kerr, A. 2012. Ecologically Appropriate Restoration Thinning in the Northwest Forest Plan Area. A Policy and Technical Analysis. Conservation Northwest, Geos Institute, Klamath-Siskiyou Wildlands Center, and Oregon Wild.

While thinning itself produces GHG emissions and reduces carbon stocks temporarily, it also accelerates the growth of trees left behind so over the long run carbon stocks accumulate not only in large, older trees, but in snags and downed logs that recycle stored carbon into the soil. In this way timber harvest and increased carbon storage are compatible. As noted by Busing and Garman (2002), "[t]hinning from below can expedite the development of large live and dead trees, and canopy height diversity without greatly diminishing wood quantity or quality."[41]

Alternatives to clearcutting, chemicals and fertilizers

As referenced earlier, clearcuts are carbon sequestration dead zones for roughly 13 years after harvest because emissions from the decay and combustion of logging residuals and losses of soil carbon outweigh any sequestration by seedlings and new growth (Appendix H). Moreover, the application of chemical herbicides and fertilizers used to suppress competing vegetation and enhance seedling growth in clearcuts generates additional carbon emissions above and beyond the emissions associated with timber harvest because they contain embodied carbon that is released into the atmosphere in a short period of time.[42] In addition, nitrogen-based fertilizers (urea being the most common) applied to forestlands increases atmospheric nitrous oxide, the third most harmful greenhouse gas behind methane and CO2.

Profitable, climate smart techniques that leave forest cover intact and obviate the need for use of chemical herbicides and fertilizers are routinely practiced by small scale, sustainable forestry operations Zena Forest, Hyla Woods and Shady Creek Forest Resources. Techniques include individual and group tree selection, small patch cuts, thinning, and management for a diverse mix of both hardwoods and softwoods.[43] Wood is removed but a forest is left behind. The practicality and ecological benefits of alternatives to conventional clearcutting have been extremely well documented.[44] The relative climate benefits of such practices are fourfold – (a) the areal extent of carbon sequestration dead zones is minimized or eliminated; (b) emissions associated with timber harvesting, chemicals, and fertilizers are reduced or eliminated; (c) the structural diversity and climate resiliency of stands improve, and (d) permanent carbon storage on the land is significantly higher.

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[41] Busing, R.T., Garman, S.L., 2002. "Promoting old-growth characteristics and long-term wood production in Douglas-fir forests." *Forest Ecology and Management* 160 (2002): 161-175.

[42] See, e.g. Lal, R., 2004. "Carbon emissions from farm operations." Environment International 30 (2004): 981-990.

[43] For a profile of these foresters and their techniques, see Segerstrom, C., 2017. Slow Wood: Reimagining the value and values of timber. *Eugeneweekly.com*, August 3rd, 2017. Available online at: http://www.eugeneweekly.com/20170803/lead-story/slow-wood.

[44] See, e.g. Franklin, J.F., Berg, D.R., Thornburgh, D.A., Tappeiner, J.C., 1997. "Alternative silvicultural approaches to timber harvesting: variable retention harvest systems." Chapter 7 in Kohm, K.A., Franklin, J.F., eds. Creating a Forestry for the 21st Century. Washington, DC: Island Press.

Long rotations

Even if conventional clearcutting and even aged practices are used, significantly extending rotation lengths (time between harvests) can mitigate many of the adverse impacts and flip high emissions landscapes back into those that accumulate and store high densities of carbon.

The ecological and economic benefits of long rotations have been extremely well researched and established. Curtis (1997) summarized a number of key benefits, including reduced land area in recent clearcut condition, larger trees and higher quality wood, less need for herbicides, higher quality wildlife habitat, more stable hydrological regimes (lower peak flows and higher dry season flows), enhanced long-term site productivity and improved carbon storage.[45] Economically, long rotations vastly improve the standing asset value of a forest. In an analysis of the effects of extended rotations on timber supply and three asset value categories – carbon, conservation, and standing timber – Talberth (2015) found that by extending rotation age from 40 to 240 years Oregon can boost the permanent value of state forestland in the northern Coast Range from roughly $3.9 billion to over $21 billion (Appendix L).[46] Modeled carbon stocks in a 240-year rotation regime were 3.5 times greater than the 40-year rotation baseline.

Extending rotation lengths is also critical for transforming bad actors into good ones from a carbon emissions standpoint. The key is the amount of land area in recent clearcut condition at one time – i.e. carbon sequestration dead zones. From a net ecosystem productivity (NEP) perspective, such lands are not only sequestration dead zones, but also significant net emissions sources due to the decay of logging residuals (Appendix H). Short rotations mean a greater areal extent of these carbon emitting dead zones since more land is clearcut each year relative to longer rotation lengths.

Appendix K and Figure 4 illustrate the effects of extended rotations on annual emissions using the timber harvest emissions approach summarized in Section 1. The bad actor scenario depicted here is modeled as an industrial forestland owner using conventional clearcutting practices on a 35-year rotation across its 10,000-acre ownership. The good actor scenario depicted extends that rotation length to 120 years. The analysis takes into account the area of land in recent clearcut condition (0-13 age class) at any one time, the foregone sequestration associated with those lands, the emissions on those lands from decay of logging residuals, timber harvest emissions, and sequestration by lands not affected by timber harvest in any one year. Appendix K provides details on all the key numerical assumptions. One key metric is the extent of carbon sequestration dead zones under each scenario. Under the bad actor scenario,

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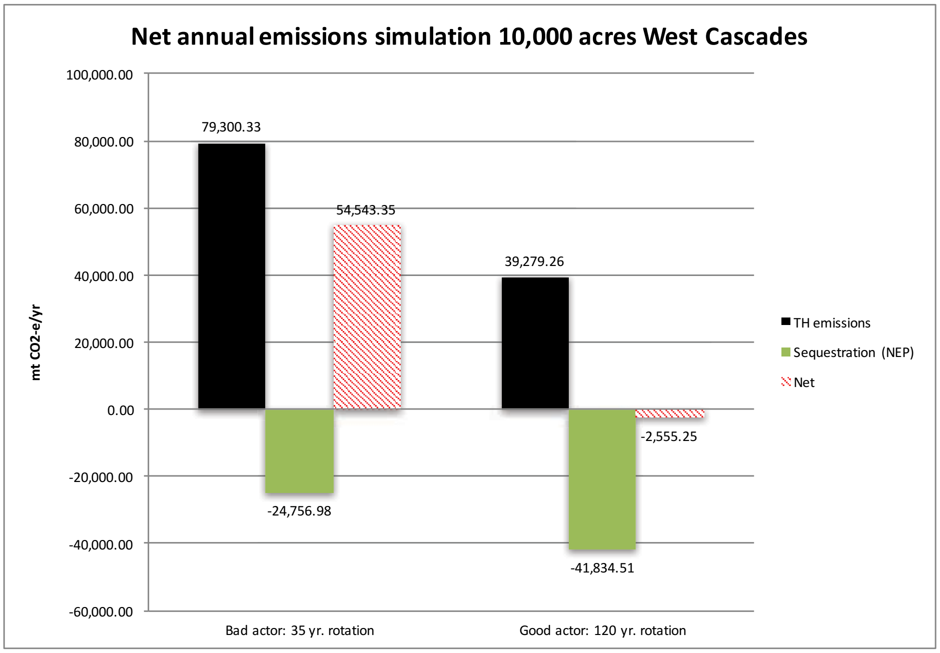
[45] Curtis, R.O., 1997. "The role of extended rotations." Chapter 10 in Kohm, K.A., Franklin, J.F., eds. Creating a Forestry for the 21st Century. Washington, DC: Island Press.

[46] Talberth, J., 2015. Testimony of Dr. John Talberth before the Oregon Board of Forestry. Subcommittee on alternative forest management plans for northwest state forests. October 19th, 2015. Lake Oswego, OR: Center for Sustainable Economy.

acres falling into the 0-13 age class are maintained at 4,000 acres per year, while under the good actor scenario this figure is 1,667 acres.

The analysis is preliminary, and since use of NEP is a significant departure from using conventional measures such as net primary productivity (NPP) as a basis for sequestration, will need to be validated through other methods and reconciled with mass balance requirements since the short rotation scenario implies a steady reduction in carbon density over time.[47] Nonetheless it suggests that moving from a 35 to a 120-year rotation has the potential to transform intensively managed ownerships from significant net sources of carbon emissions (>54,000 mtCO2-e/yr) to ones that sequester more CO2 than they emit (<-2,555 mt CO2-e/yr) and thereby build carbon density over time.

Figure 4: The effects of extended rotations on net annual carbon emissions of a typical managed landscape in the Oregon Cascades



Afforestation

Afforestation is the process of establishing forests where they do not presently exist because the land has been converted to other uses or because forests were not established there by natural processes. There has been no assessment of afforestation potential in Oregon, however, one way to consider the potential is to retrace how much forestland has been

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[47] The mass balance requirement is simply the law of conservation of matter and energy. If short rotation plantations deplete carbon storage over time then it is important to understand what carbon pools are being drawn down (i.e. soils and live trees) and what pools are increasing (atmosphere) and how these balance over time.

converted to agricultural land since it can theoretically be reverted back to forest and ecologically sustained.

In the Willamette Valley, for example, historic records show that 59% of the land base was occupied by forests, woodlands, and pine-oak savannas.[48] Today, forests and woodlands account for just 34%.[49] The native pine-oak savanna has been reduced to just tiny fraction of its original extent. So the afforestation potential is there. But a good portion of this land is now in high-value agricultural uses that will be costly to convert back to forests. The afforestation potential is greater, however, on marginal, frequently idled, and non-food producing farmlands such as grass seed and Christmas tree farms since the opportunity costs are much less. Additional afforestation opportunities may be found on residential lands in rural and suburban areas, since many of these properties include large, undeveloped open spaces that are not presently sustaining any intensive land uses.

7. The timber industry argues that if wood products consumption falls, it will be replaced by more carbon intensive substitutes. But there are many less carbon intensive alternatives to Oregon's wood products including solar and wind instead of biomass for energy, conservation, efficiency, bamboo and other alternative fibers for paper products, and recycled and reused materials.

The timber industry often makes the claim that reducing its harvests to protect environmental values will have the unintended consequence of increasing consumption of substitutes that have a higher carbon footprint. Using wood in buildings rather than concrete or steel, or using biomass for energy rather than fossil fuels are the most often cited examples.[50]

In buildings, there is ample documentation to show that life-cycle emissions associated with wood relative to concrete and steel are lower. But these analyses lack data on forest practices at the source. For example, wood derived from deforestation or the conversion of old growth forests to tree plantations carries with it a high carbon footprint that lasts generations and overshadows any beneficial substitution effect. Moreover, most studies fail to account for the fact that storage in wood products is only temporary, requiring replacement down the road with a renewed cycle of timber harvest emissions and reduced sequestration capacity.

For biomass to energy, many studies show that it is just as bad or even worse than burning coal. In a recent report issued by Chatham House, researchers found that "[o]verall, while some instances of biomass energy use may result in lower life-cycle emissions than fossil fuels, in

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[48] Christy, J.A., Alverson, E.R., 2011. "Historical vegetation of the Willamette Valley, Oregon, circa 1850. Northwest Science 85(2): 93-107.

[49] Wilson, T.S., Sorenson, D.G. Willamette Valley Ecoregion Summary. USGS Land Cover Trends Project, available online at: https://landcovertrends.usgs.gov/west/eco3Report.html.

[50] See, e.g. Wilson, J., 2006. Using wood products to reduce global warming. Chapter 7 in Forests, Carbon and Climate Change. A Synthesis of Science Findings. Oregon Forest Resources Institute, OSU College of Forestry and the Oregon Department of Forestry.

most circumstances, comparing technologies of similar ages, the use of woody biomass for energy will release higher levels of emissions than coal and considerably higher levels than gas."[51] The notion that biomass is somehow a clean fuel has been widely discredited.

For these and other reasons, several studies have come to the conclusion that taking land out of timber production and putting it into conservation status has a net climate mitigation benefit, even after taking these substitution effects into account.[52]

Moreover, for most wood product end uses, there are many less carbon intensive substitutes available, including solar and wind instead of biomass for energy, bamboo and other alternative fibers for paper products, and recycled and reused materials. Relative to wood, the climate benefits of these alternative fibers have been well established. For example, fast growing bamboo plantations grown on agricultural lands have been shown to be carbon neutral or even carbon negative thereby reducing pressure on forests so they can be left to accumulate carbon.[53] Industrial, non-cannabis hemp has a wide diversity of end uses that can displace wood derived paper and building materials and result in substantial carbon savings.[54] The assumption that all wood substitutes are more carbon intensive is unfounded.

The bottom line is that logging to produce wood products of any kind generates significant carbon emissions and reduces carbon sequestration capacity with certainty while the climate mitigation benefits of substituting wood for other materials is speculative and extremely case dependent. As a result, the practice of promoting wood products as a climate solution regardless of how they were sourced and regardless of the end use has no scientific validity.

III. Legislative options

8. Legislative interventions consistent with global climate change mitigation goals should simultaneously reduce timber harvest related emissions, enhance sequestration, increase permanent carbon storage, and improve climate resiliency.

Legislative interventions are needed to enroll the timber industry into Oregon's climate agenda because the Oregon Forest Practices Act does not include any relevant statutory provisions.

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[51] Brack, D., 2017. Woody Biomass for Power and Heat: Impacts on the Global Climate. London, UK: The Royal Institute of International Affairs, Chatham House.

[52] See, e.g. Keith, H., Lindenmayer, D., Macintosh, A., Mackey, B. 2015. Under what circumstances do wood products from native forests benefit climate change mitigation? PLoS ONE 10(10): e0139640., doi:10.1371/journal.pone.0139640

[53] Vogtlander, J.G., Van der Lugt, P., 2015. The Environmental Impact of Industrial Bamboo Products: Life-cycle Assessment and Carbon Sequestration. INBAR Technical Report No. 35. The Netherlands: MOSO Research and Development Center and the Delft University of Technology.

[54] Johnston, S., 2016. The Environmental Benefits of Industrial Hemp. Nellysford, VA: Virginia Industrial Hemp Coalition.

Nor can voluntary agreements or incentives like carbon offsets have much of an impact because they are at present and likely to remain very limited in scope, and effectiveness.

During the 2018 legislative session, there are three legislative approaches that have been suggested by CSE and its partners to simultaneously advance four essential forest carbon goals as swiftly as possible (1) reducing emissions from logging; (2) enhancing sequestration capacity; (3) increasing permanent carbon storage back towards natural capacity, and (4) expediting the restoration of industrial tree plantations into climate resilient forests. The approaches, explored in more detail below, include cap-and-invest, forest carbon tax and reward, and an Oregon Forest Resiliency Act.

9. Legislative option 1: Enrolling forestland owners who are major greenhouse gas emitters into emerging cap-and-invest legislation (SB 1070).

The cap and invest approach has been drafted into legislation in the form of SB 1070, at the time of this writing.[55] The approach is synonymous with cap and trade, and is built around a system of declining allowances for CO2 emissions from major sources, auctions of excess allowances, investment of auction revenues into various funds that advance climate mitigation and adaptation goals, use of offsets where compliance is prohibitively expensive and penalties for noncompliance. Major sources include those that generate 25,000 mt CO2-e per year from their use of electricity, fossil fuels and industrial processes. It has been estimated that 100 facilities and businesses would be regulated under this standard.[56] Emissions from farms or logging operations are excluded. The current targets for emissions reductions achieved through this approach include:

a) A statewide greenhouse gas emissions goal for the year 2025 to limit greenhouse gas emissions to levels that are at least 20 percent below 1990 levels;
b) A statewide greenhouse gas emissions limit for the year 2035 that limits greenhouse gas emissions to levels that are at least 45 percent below 1990 levels; and
c) A statewide greenhouse gas emissions limit for the year 2050 that limits greenhouse gas emissions to levels that are at least 80 percent below 1990 levels.

Modifying SB 1070 to address emissions from industrial logging and threats to climate resiliency is relatively straightforward. The Sustainable Energy and Economy Network (SEEN) has submitted proposed amendments that are relatively minor in length and complexity but will have a significant impact by helping to incentivize climate smart practices and phase out harmful ones and enroll big emitters (forestland owners whose practices emit 25k+ CO2 each

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[55] The Legislature has posted a useful overview of SB 1070 here: https://www.oregonlegislature.gov/helm/workgroup_materials/Overview%20of%20SB%201070%20(2017).pdf

[56] Oregon Department of Environmental Quality. 2017. Considerations for Designing a Cap-and-Trade Program in Oregon. Salem, OR: DEQ. Available online at: http://www.oregon.gov/deq/FilterDocs/ghgmarketstudy.pdf.

year) as covered entities regulated by the cap-and-invest market on par with other sources (Appendix Q).[57] The amendments would achieve the following:

1) Expands the list of covered entities to include forestland owners whose logging practices generate 25,000 metric tons CO2-e or more on an annual basis. This is about the level of emissions generated by a single, 120 acre clearcut in western Oregon.
2) Directs the Environmental Quality Commission to adopt a method for calculating timber harvest related emissions that takes into account loss of carbon storage, loss of sequestration capacity, emissions associated with decay of logging residuals, and emissions associated with chemical pesticides and fertilizers.
3) Reduces emissions associated with clearcutting and conventional logging practices on the same timetable as other covered entities (20% by 2025; 45% by 2035; 80% by 2050).
4) Establishes the date of enactment as the baseline year.
5) Exempts timber harvest emissions associated with climate-smart practices from the cap.
6) Refines existing Oregon Global Warming Commission duties to track and evaluate climate smart practices that increase carbon storage back to historic levels and reduce emissions associated with logging.
7) Requires registration and reporting of timber harvest-related emissions.
8) Ensures accountability of offset projects through public review mechanisms.

Calculation methods for emissions have already been worked out, so the EQC process will not be that complex. Reporting infrastructure is already in place. Private timberland owners are already required to notify the State Forester and Department of Revenue and Taxation before commencing of logging operations with all the information needed to keep track of associated emissions.[58] The Forest Service and BLM have separate notification systems that are just as easy to access. And, as discussed earlier, a typology of climate smart practices has already been well researched. So it appears the task of including industrial forestland owners into the SB 1070 framework is doable without any significant increase in reporting by covered entities.

10. Legislative option 2: Forest carbon tax and reward is a feasible market-based approach for dramatically scaling up climate smart practices and creating thousands of new jobs in the woods.

In the run-up to the 2017 Legislative Assembly outgoing Representative Peter Buckley and incoming Representative Pamela Marsh facilitated the drafting of model forest carbon tax and reward legislation (FCTR) with CSE (Appendix O).[59] The overall goal would be to tax high-

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[57] A copy of SEEN's submission can be accessed here: https://www.oregonlegislature.gov/helm/workgroup_materials/WG%201%20-%20Public%20Comments%20from%20Sustainable%20Energy%20Economy%20Network.pdf.

[58] An overview of Oregon's e-notification system can be accessed here: http://www.oregon.gov/ODF/Working/Pages/ENotification.aspx.

[59] A full text version of the draft legislation can be accessed here:

emissions (bad actor) practices and use proceeds to provide cost-share assistance to forestland owners implementing climate smart forest practices (good actors). The legislation would add a carbon emissions component to current timber harvest taxes collected each year. The tax would be would be levied on all volume harvested in excess of growth by natural (non-plantation) forests across the owner's property at a rate pegged to the federal social cost of carbon (SCC), which stands at about $42/tCO2-e.

After accounting for emissions associated with timber removals, foregone sequestration, decay of logging residuals, and forest chemicals, the initial gross SCC-based charge would be roughly $210 per thousand board feet (mbf) harvested for a typical landowner in western Oregon. The State Forester, working with the Oregon Global Warming Commission, would meet annually to adjust this rate taking the best scientific information available into account.

Forestland owners would receive up to a 50% credit against the gross levy for the proportion of lands managed under third-party certified long-term carbon storage agreements. In addition, all volume extracted from such lands would be exempted. So the net tax would be computed in the following manner:

TAX = (VTH – VNG – VCS) x $210 x (1-CR), where

TAX = Net tax paid by forest landowner
VTH = Volume of annual timber harvest
VNG = Volume of natural forest growth
VCS = Volume removed from climate smart forest practices
CR= Proportion of land managed under certified storage agreement (50% max)

Tax revenues would be deposited into a Forest Carbon Incentive Fund (FCIF), jointly managed by the Department of Forestry (ODF) and the Oregon Global Warming Commission (OGWC). Payments from the fund would be made to qualified landowners to offset costs associated with climate smart forest practices. ODF and OGWC would develop, maintain, and update a list of approved climate smart practices and information about their efficacy and cost. Funds would also be used to offset all ODF and OGWC expenses associated with administering the FCIF and also support research and monitoring activities.

A FCTR program in Oregon can be expected to have the following climate and economic benefits:

- Hundreds of millions of dollars could be available each year to invest in climate smart forest practices. A hypothetical analysis of potential tax revenues from western Oregon industrial forestlands, albeit with a somewhat different methodology than what is set forth in LC 2875, suggests that gross revenues (before credits and exemptions) could top $500 million per year (Appendix P). Net revenues could easily top $100 million per year.

- Many new jobs would be created. An investment of $100 million each year in climate smart forest practices could support between 3,000 and 4,000 new jobs according to standard multipliers applied to forest restoration work.[60]

- Emissions from timber harvest will fall. Timber harvest related emissions will fall due to (a) less timber harvesting from conventionally managed forests; (b) a reduction in emissions associated with foregone sequestration on clearcut lands, and (c) a reduction in emissions associated with decay of logging residuals.

- Sequestration will increase. Sequestration will not be eliminated after timber harvest on lands managed in accordance with climate smart standards. Instead, sequestration will increase as stands are thinned to maximize the growth of residual trees and as current carbon sequestration dead zones revert back into healthy forests.

- Longer-lived wood products would be incentivized. The tax rate would be adjusted to account for the share of timber harvests allocated to long-lived vs. short-lived wood products, with the tax rate lower for the former.

- The amount of forestland managed with climate smart practices that result in continuous increases in carbon storage (capture and store) will dramatically increase.

- The landscape will begin a transformation away from short rotation timber plantations and towards more climate resilient natural forests.

11. Legislative option 3: An Oregon Forest Resiliency Act will help jumpstart the restoration of industrial tree plantations into climate resilient forests and include a climate test for proposed logging operations.

A third approach more directly focused on the climate risks of industrial tree plantations is a proposed Oregon Forest Resiliency Act developed by CSE as a legislative concept note (Appendix R). The proposed legislation would amend and revise the Oregon Forest Practices Act to require implementation of climate smart practices to enhance the resiliency of private forestlands to drought, disease, wildfire, floods, landslides, low summertime streamflow, thermal pollution, fish kills, regeneration failures and other threats associated with climate change. It would accomplish this through six key mechanisms:

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[60] See, e.g. Moseley, C., Nielsen-Pincus, M., 2009. Economic Impact and Job Creation from Forest and Watershed Restoration: A Preliminary Assessment. Eugene, OR: University of Oregon Ecosystem Workforce Program; BenDor, T.K., Lester, T.W., Livengood, A., 2014. Exploring and Understanding the Restoration Economy. Chapel Hill, NC: University of North Carolina.

a) Climate resiliency plans (CRPs). Requires large forestland owners (>5,000 acres) to prepare and adhere to climate resiliency plans that describe existing conditions, climate threats, and climate smart practices that will be undertaken to comply with requirements of this Act. CRPs also must include hard targets for rebuilding carbon density, one of the key policy recommendations from the Oregon Global Warming Commission.[61] CRPs would be based on the best available science and subject to multi-agency review and approval. CRPs would serve as a comprehensive permit and require public participation, multi-agency review and approval.

b) A climate test for timber harvest plans (THPs). Requires large forestland owners (>5,000 acres) proposing clearcut harvest methods to file a THP for approval by the State Forester describing harvest, regeneration and resource protection measures needed to ensure the climate resiliency of future stands. THPs must also include a consistency determination with CRPs. This provision would, in essence, provide a "climate test" applicable to timber harvesting. To pass the test and receive authorization, a proposed timber harvest would have to ensure that it helps achieve both carbon density and climate resiliency goals set forth in the CRP.

c) Protection and restoration of native riparian vegetation and drinking watersheds. To protect and restore native riparian vegetation and drinking water supplies, establishes water resource management areas (WRMAs) along all rivers, streams, lakes, wetlands and shorelines consistent with the best available science and the state's non-degradation policy. Designates all surface drinking water assessment areas as WRMAs. Prohibits clearcutting and chemical sprays in WRMAs. Directs the State Forester, in consultation with the Department of Environmental Quality and Department of Fish and Wildlife to develop a list of acceptable timber harvest methods within WRMAs that ensure the resiliency of water supplies and native fish and wildlife populations to climate change and enhance the role of riparian zones in mitigating wildfire threat.

d) Protection and restoration of climate resilient forests. Prohibits the conversion of any remaining natural, late successional or old growth forests into tree plantations. For entities required to prepare CRPs, requires allocation of a portion of forestlands to protect or promote the establishment of climate resilient stands of late successional and old growth forest (LSOG) through appropriate silvicultural and restoration techniques. Establishes criteria for selection of LSOG management areas. Requires delineation of such lands on maps and Department of Fish and Wildlife approval.

e) Alternatives to clearcutting and timber plantations. Provides exemptions from reforestation requirements for climate smart practices that rely on natural regeneration

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[61] Oregon Global Warming Commission. 2017. Forest Carbon Policy Choices, Powerpoint slide deck prepared for the July 28th meeting. Available online at: http://www.keeporegoncool.org/meeting/oregon-global-warming-commission-meeting-july-2017.

and leave sufficient amounts of biological legacy to maintain forest cover, protect soil and watershed conditions, and enhance long term site productivity.

IV. Future iterations of this report

CSE has prepared this report as a convenient source of scientific and technical information relevant to forest carbon policy in Oregon as well as a repository for legislative concepts being fielded to address the twin threats associated with logging related emissions and loss of climate resiliency. For most policy makers, the learning curve is steep, and so we have attempted to make all of the data presented as transparent and easy to understand as possible with all of the key sources extensively documented in footnotes, hyperlinks, and the appendices. It will be maintained as a living, open source document where researchers will be invited to share alternative data sources as needed to replace ones that are either outdated or superseded by more precise studies. Alternative views and competing conclusions drawn from the data will be noted and incorporated into the next iterations where appropriate.

V. Acknowledgements

CSE would like to extend our warmest thanks to the many people who reviewed earlier drafts of this document and help us improve both the accuracy of the information presented as well as the conclusions drawn. Special thanks to Ernie Niemi and Doug Heiken for their constructive edits and suggestions. We would also like to thank the Laird Norton Family Foundation and the Alex C. Walker Foundation for their generous financial support of this work.

Appendix A

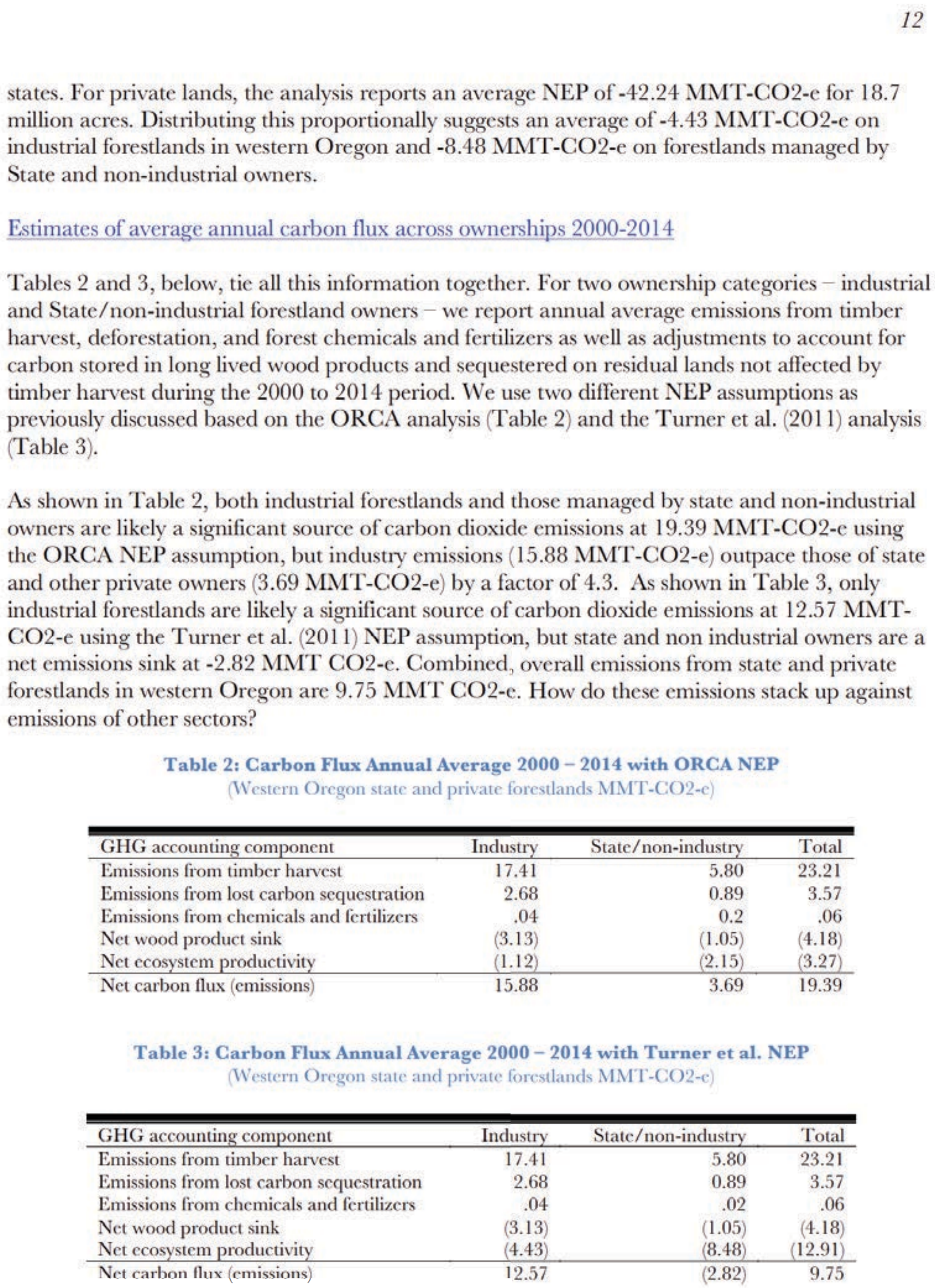
Table 2A. Growth, Removals and Mortality of CO2 equivalent, by ecoregion

All Oregon

Source: FIA (2001-2005; 2011-2015)

	Public										Private				Total	
	NFS		BLM		NPS		State		Other Public		Private Industry		Private Non-industrial		Total	
	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE	Total	SE
	thousand metric tons per year															
Time 1	1,776,928	27,917	434,725	22,653	22,672	7,389	153,243	12,212	15,077	5,741	610,831	26,036	204,422	17,048	3,217,898	44,066
Gross Ingrowth																
Ingrowth	2,711	87	950	163	13	5	249	59	88	41	6,127	490	1,175	181	11,313	549
Reversion	266	60	20	11	--	--	82	57	13	13	15	10	258	127	654	152
Total	2,977	103	969	164	13	5	331	85	101	43	6,142	490	1,433	220	11,966	566
Accretion	29,998	410	11,206	528	321	107	4,512	331	458	157	22,427	1,001	6,836	584	75,758	1,181
Gross Growth	32,975	425	12,175	564	334	111	4,843	368	559	174	28,569	1,152	8,269	661	87,724	1,322
Mortality	15,847	765	1,872	248	265	120	938	231	63	36	3,385	393	890	121	23,260	933
Removals																
Cut Trees	2,996	343	760	256	--	--	2,741	742	299	216	24,013	2,345	3,890	867	34,698	2,569
Diversion	38	15	10	11	--	--	--	--	--	--	--	--	7	5	55	19
Total	3,035	343	771	256	--	--	2,741	742	299	216	24,013	2,345	3,896	867	34,754	2,569
Net Growth	17,129	870	10,303	606	70	80	3,905	405	496	157	25,183	1,146	7,379	625	64,465	1,586
Net Change	14,094	933	9,532	635	70	80	1,165	856	197	212	1,171	2,682	3,483	953	29,711	3,178
Time 2	1,917,834	29,052	529,110	24,300	23,354	7,555	164,942	13,929	16,936	6,153	622,608	29,434	238,728	19,396	3,513,511	48,602

Appendix B



states. For private lands, the analysis reports an average NEP of -42.24 MMT-CO2-e for 18.7 million acres. Distributing this proportionally suggests an average of -4.43 MMT-CO2-e on industrial forestlands in western Oregon and -8.48 MMT-CO2-e on forestlands managed by State and non-industrial owners.

Estimates of average annual carbon flux across ownerships 2000-2014

Tables 2 and 3, below, tie all this information together. For two ownership categories – industrial and State/non-industrial forestland owners – we report annual average emissions from timber harvest, deforestation, and forest chemicals and fertilizers as well as adjustments to account for carbon stored in long lived wood products and sequestered on residual lands not affected by timber harvest during the 2000 to 2014 period. We use two different NEP assumptions as previously discussed based on the ORCA analysis (Table 2) and the Turner et al. (2011) analysis (Table 3).

As shown in Table 2, both industrial forestlands and those managed by state and non-industrial owners are likely a significant source of carbon dioxide emissions at 19.39 MMT-CO2-e using the ORCA NEP assumption, but industry emissions (15.88 MMT-CO2-e) outpace those of state and other private owners (3.69 MMT-CO2-e) by a factor of 4.3. As shown in Table 3, only industrial forestlands are likely a significant source of carbon dioxide emissions at 12.57 MMT-CO2-e using the Turner et al. (2011) NEP assumption, but state and non industrial owners are a net emissions sink at -2.82 MMT CO2-e. Combined, overall emissions from state and private forestlands in western Oregon are 9.75 MMT CO2-e. How do these emissions stack up against emissions of other sectors?

Table 2: Carbon Flux Annual Average 2000 – 2014 with ORCA NEP
(Western Oregon state and private forestlands MMT-CO2-e)

GHG accounting component	Industry	State/non-industry	Total
Emissions from timber harvest	17.41	5.80	23.21
Emissions from lost carbon sequestration	2.68	0.89	3.57
Emissions from chemicals and fertilizers	.04	0.2	.06
Net wood product sink	(3.13)	(1.05)	(4.18)
Net ecosystem productivity	(1.12)	(2.15)	(3.27)
Net carbon flux (emissions)	15.88	3.69	19.39

Table 3: Carbon Flux Annual Average 2000 – 2014 with Turner et al. NEP
(Western Oregon state and private forestlands MMT-CO2-e)

GHG accounting component	Industry	State/non-industry	Total
Emissions from timber harvest	17.41	5.80	23.21
Emissions from lost carbon sequestration	2.68	0.89	3.57
Emissions from chemicals and fertilizers	.04	.02	.06
Net wood product sink	(3.13)	(1.05)	(4.18)
Net ecosystem productivity	(4.43)	(8.48)	(12.91)
Net carbon flux (emissions)	12.57	(2.82)	9.75

Appendix C

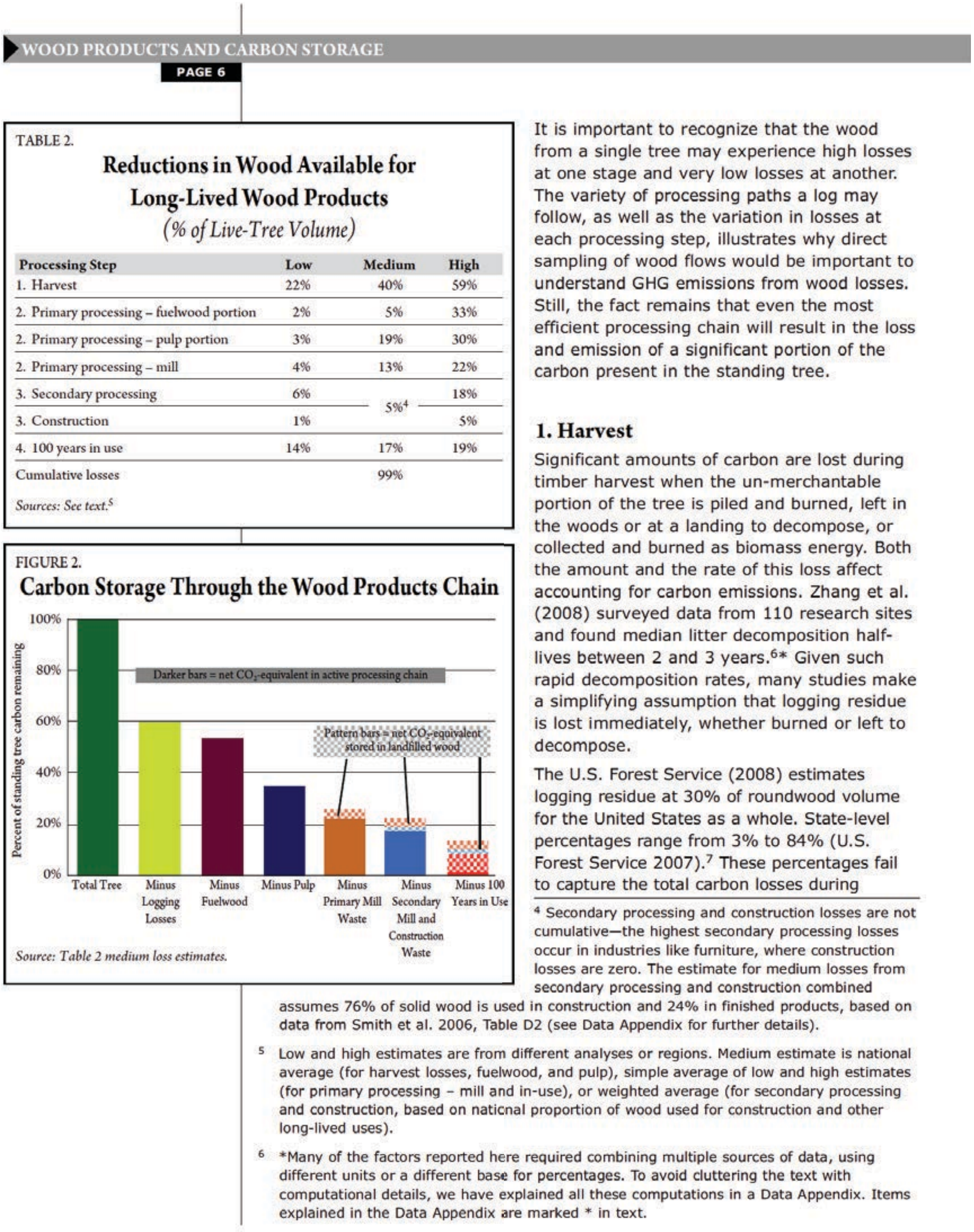


TABLE 2.

Reductions in Wood Available for Long-Lived Wood Products

(% of Live-Tree Volume)

Processing Step	Low	Medium	High
1. Harvest	22%	40%	59%
2. Primary processing – fuelwood portion	2%	5%	33%
2. Primary processing – pulp portion	3%	19%	30%
2. Primary processing – mill	4%	13%	22%
3. Secondary processing	6%	5%[4]	18%
3. Construction	1%		5%
4. 100 years in use	14%	17%	19%
Cumulative losses		99%	

Sources: See text.[5]

FIGURE 2.

Carbon Storage Through the Wood Products Chain

Source: Table 2 medium loss estimates.

It is important to recognize that the wood from a single tree may experience high losses at one stage and very low losses at another. The variety of processing paths a log may follow, as well as the variation in losses at each processing step, illustrates why direct sampling of wood flows would be important to understand GHG emissions from wood losses. Still, the fact remains that even the most efficient processing chain will result in the loss and emission of a significant portion of the carbon present in the standing tree.

1. Harvest

Significant amounts of carbon are lost during timber harvest when the un-merchantable portion of the tree is piled and burned, left in the woods or at a landing to decompose, or collected and burned as biomass energy. Both the amount and the rate of this loss affect accounting for carbon emissions. Zhang et al. (2008) surveyed data from 110 research sites and found median litter decomposition half-lives between 2 and 3 years.[6]* Given such rapid decomposition rates, many studies make a simplifying assumption that logging residue is lost immediately, whether burned or left to decompose.

The U.S. Forest Service (2008) estimates logging residue at 30% of roundwood volume for the United States as a whole. State-level percentages range from 3% to 84% (U.S. Forest Service 2007).[7] These percentages fail to capture the total carbon losses during

---

[4] Secondary processing and construction losses are not cumulative—the highest secondary processing losses occur in industries like furniture, where construction losses are zero. The estimate for medium losses from secondary processing and construction combined assumes 76% of solid wood is used in construction and 24% in finished products, based on data from Smith et al. 2006, Table D2 (see Data Appendix for further details).

[5] Low and high estimates are from different analyses or regions. Medium estimate is national average (for harvest losses, fuelwood, and pulp), simple average of low and high estimates (for primary processing – mill and in-use), or weighted average (for secondary processing and construction, based on national proportion of wood used for construction and other long-lived uses).

[6] *Many of the factors reported here required combining multiple sources of data, using different units or a different base for percentages. To avoid cluttering the text with computational details, we have explained all these computations in a Data Appendix. Items explained in the Data Appendix are marked * in text.

Appendix D

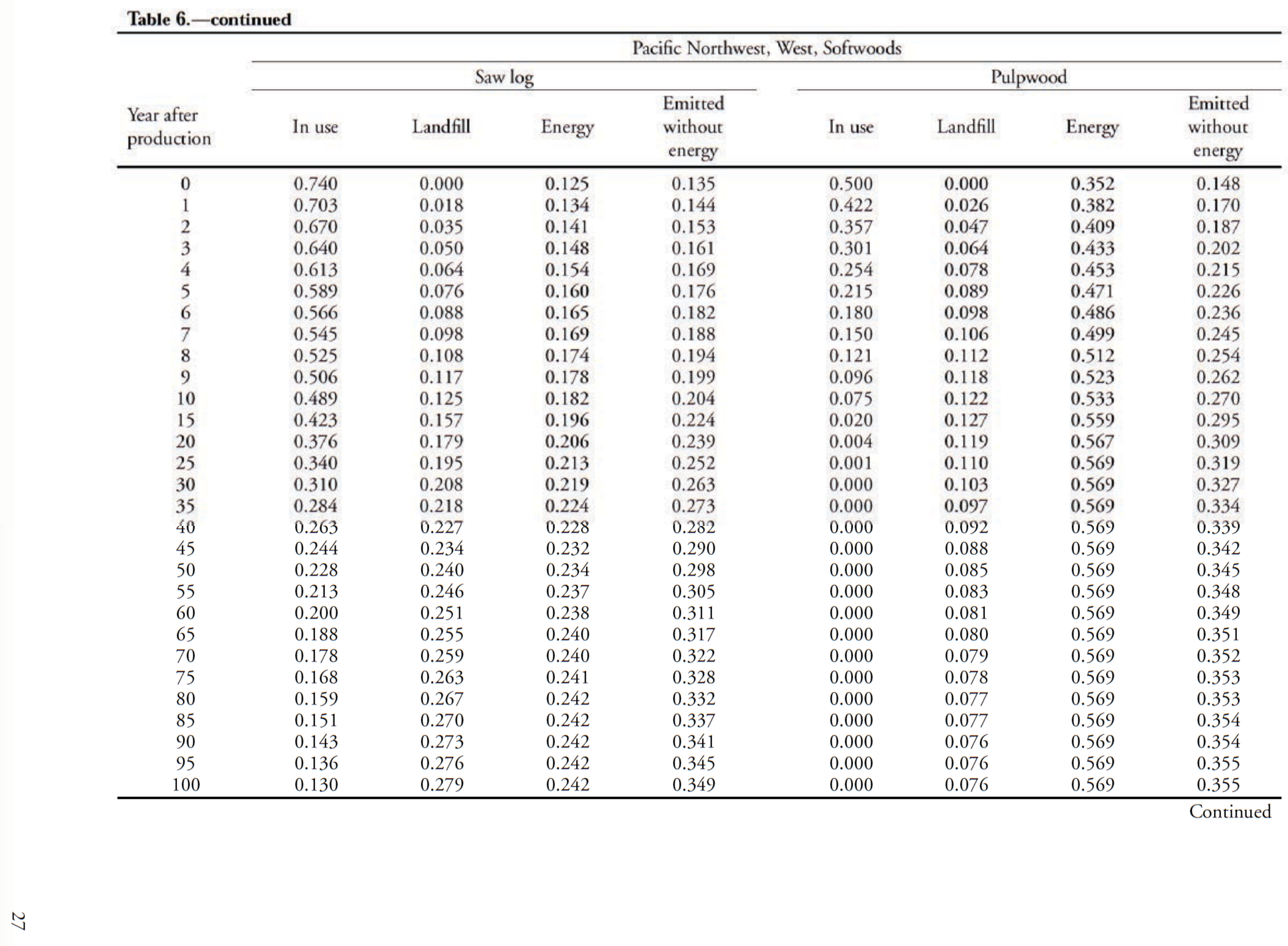


Table 6.—continued

Year after production	Pacific Northwest, West, Softwoods							
	Saw log				Pulpwood			
	In use	Landfill	Energy	Emitted without energy	In use	Landfill	Energy	Emitted without energy
0	0.740	0.000	0.125	0.135	0.500	0.000	0.352	0.148
1	0.703	0.018	0.134	0.144	0.422	0.026	0.382	0.170
2	0.670	0.035	0.141	0.153	0.357	0.047	0.409	0.187
3	0.640	0.050	0.148	0.161	0.301	0.064	0.433	0.202
4	0.613	0.064	0.154	0.169	0.254	0.078	0.453	0.215
5	0.589	0.076	0.160	0.176	0.215	0.089	0.471	0.226
6	0.566	0.088	0.165	0.182	0.180	0.098	0.486	0.236
7	0.545	0.098	0.169	0.188	0.150	0.106	0.499	0.245
8	0.525	0.108	0.174	0.194	0.121	0.112	0.512	0.254
9	0.506	0.117	0.178	0.199	0.096	0.118	0.523	0.262
10	0.489	0.125	0.182	0.204	0.075	0.122	0.533	0.270
15	0.423	0.157	0.196	0.224	0.020	0.127	0.559	0.295
20	0.376	0.179	0.206	0.239	0.004	0.119	0.567	0.309
25	0.340	0.195	0.213	0.252	0.001	0.110	0.569	0.319
30	0.310	0.208	0.219	0.263	0.000	0.103	0.569	0.327
35	0.284	0.218	0.224	0.273	0.000	0.097	0.569	0.334
40	0.263	0.227	0.228	0.282	0.000	0.092	0.569	0.339
45	0.244	0.234	0.232	0.290	0.000	0.088	0.569	0.342
50	0.228	0.240	0.234	0.298	0.000	0.085	0.569	0.345
55	0.213	0.246	0.237	0.305	0.000	0.083	0.569	0.348
60	0.200	0.251	0.238	0.311	0.000	0.081	0.569	0.349
65	0.188	0.255	0.240	0.317	0.000	0.080	0.569	0.351
70	0.178	0.259	0.240	0.322	0.000	0.079	0.569	0.352
75	0.168	0.263	0.241	0.328	0.000	0.078	0.569	0.353
80	0.159	0.267	0.242	0.332	0.000	0.077	0.569	0.353
85	0.151	0.270	0.242	0.337	0.000	0.077	0.569	0.354
90	0.143	0.273	0.242	0.341	0.000	0.076	0.569	0.354
95	0.136	0.276	0.242	0.345	0.000	0.076	0.569	0.355
100	0.130	0.279	0.242	0.349	0.000	0.076	0.569	0.355

Continued

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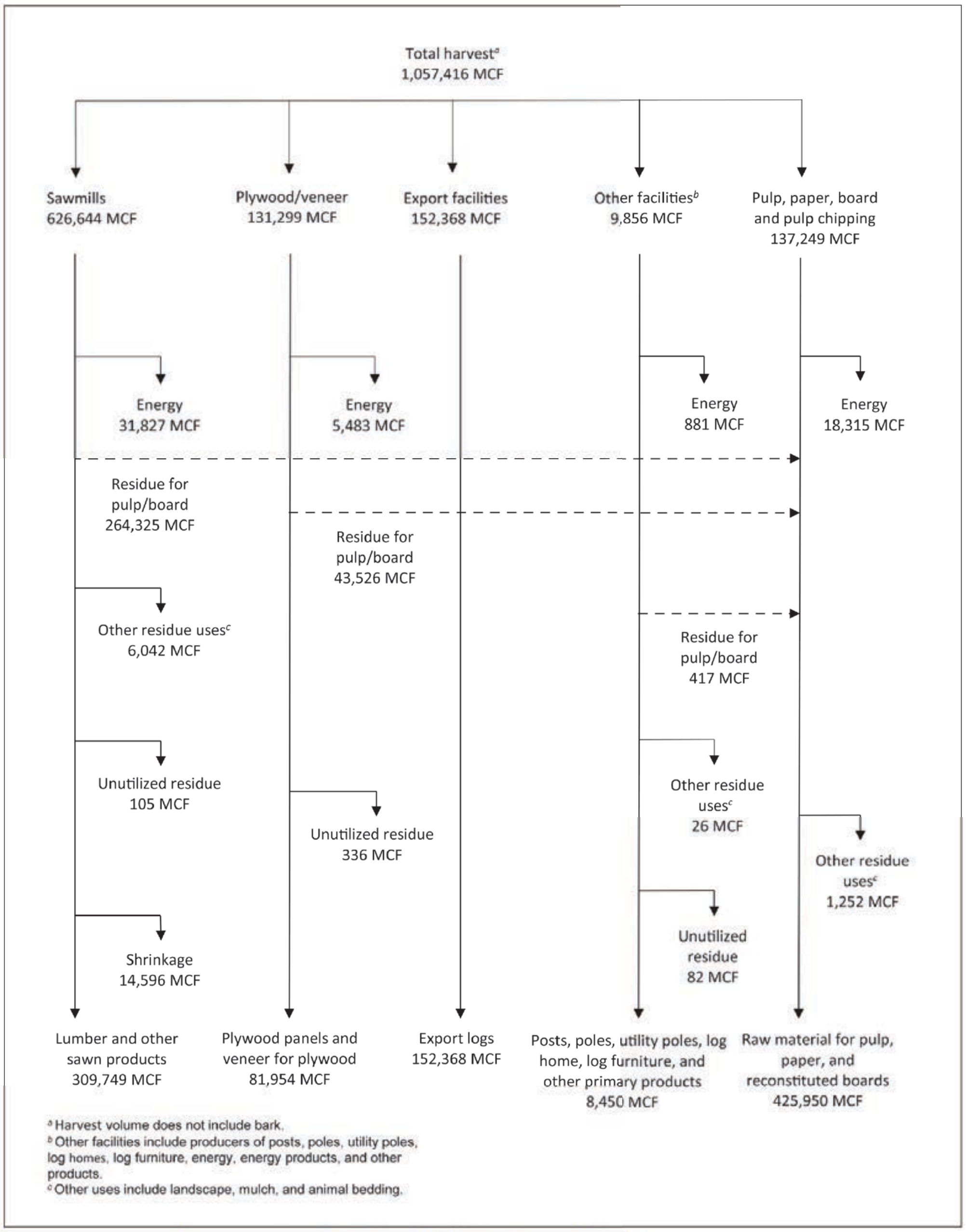
Appendix E

GENERAL TECHNICAL REPORT PNW-GTR-942



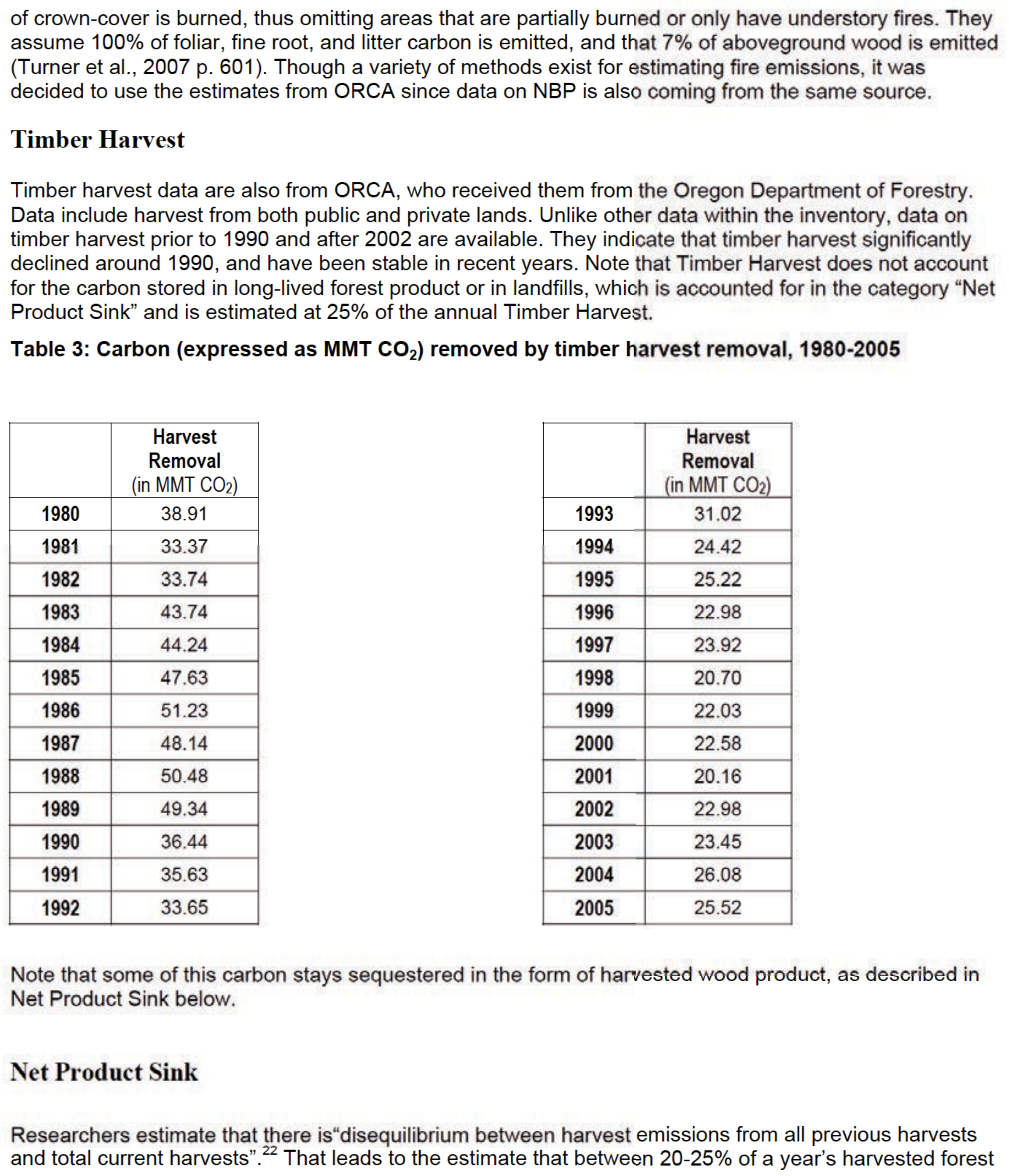
[a] Harvest volume does not include bark.

[b] Other facilities include producers of posts, poles, utility poles, log homes, log furniture, energy, energy products, and other products.

[c] Other uses include landscape, mulch, and animal bedding.

Figure 8—Oregon's timber harvest and products flow, 2013. MCF = thousand cubic feet.

Appendix F



of crown-cover is burned, thus omitting areas that are partially burned or only have understory fires. They assume 100% of foliar, fine root, and litter carbon is emitted, and that 7% of aboveground wood is emitted (Turner et al., 2007 p. 601). Though a variety of methods exist for estimating fire emissions, it was decided to use the estimates from ORCA since data on NBP is also coming from the same source.

Timber Harvest

Timber harvest data are also from ORCA, who received them from the Oregon Department of Forestry. Data include harvest from both public and private lands. Unlike other data within the inventory, data on timber harvest prior to 1990 and after 2002 are available. They indicate that timber harvest significantly declined around 1990, and have been stable in recent years. Note that Timber Harvest does not account for the carbon stored in long-lived forest product or in landfills, which is accounted for in the category "Net Product Sink" and is estimated at 25% of the annual Timber Harvest.

Table 3: Carbon (expressed as MMT CO_2) removed by timber harvest removal, 1980-2005

	Harvest Removal (in MMT CO_2)
1980	38.91
1981	33.37
1982	33.74
1983	43.74
1984	44.24
1985	47.63
1986	51.23
1987	48.14
1988	50.48
1989	49.34
1990	36.44
1991	35.63
1992	33.65

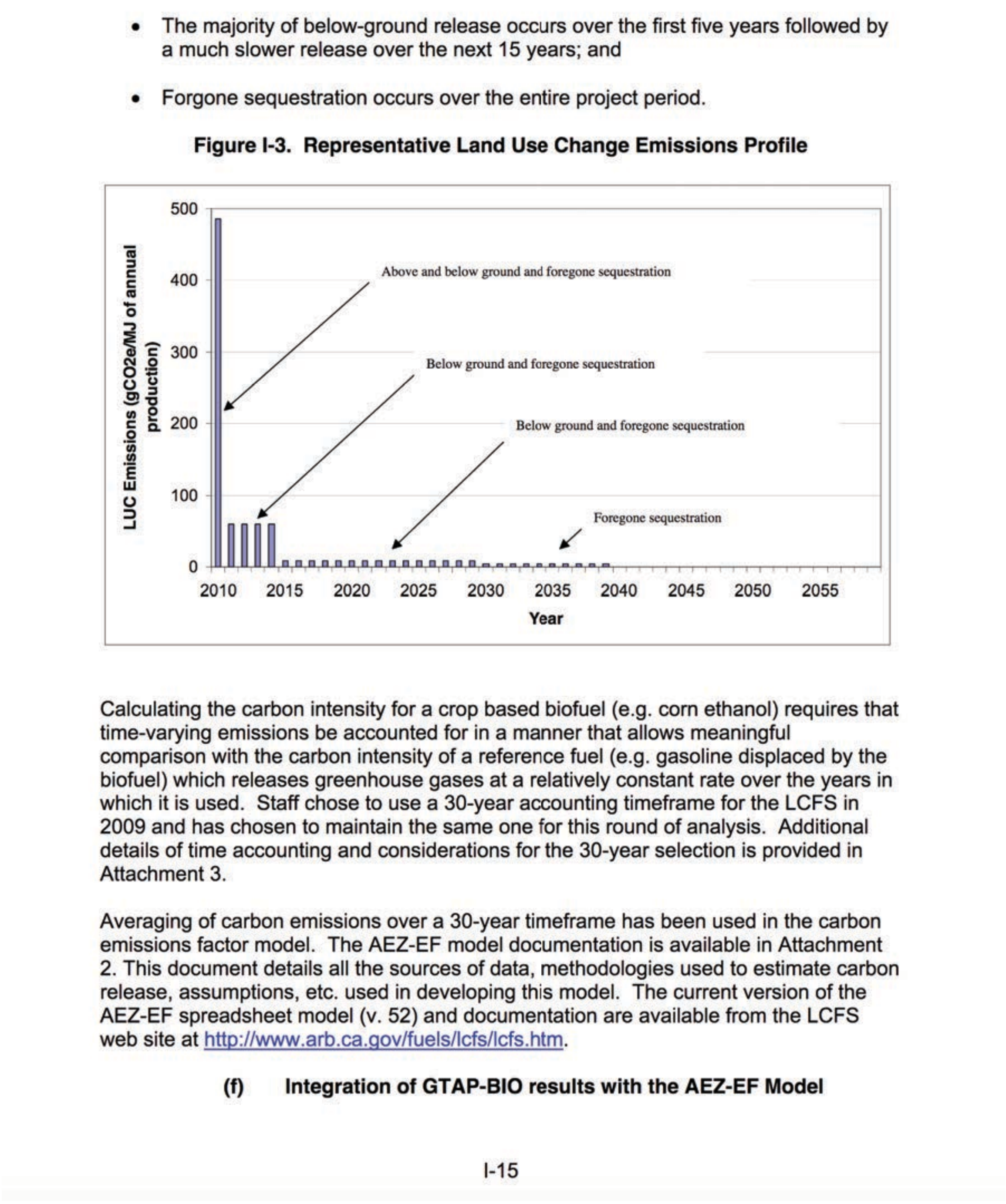
	Harvest Removal (in MMT CO_2)
1993	31.02
1994	24.42
1995	25.22
1996	22.98
1997	23.92
1998	20.70
1999	22.03
2000	22.58
2001	20.16
2002	22.98
2003	23.45
2004	26.08
2005	25.52

Note that some of this carbon stays sequestered in the form of harvested wood product, as described in Net Product Sink below.

Net Product Sink

Researchers estimate that there is"disequilibrium between harvest emissions from all previous harvests and total current harvests".[22] That leads to the estimate that between 20-25% of a year's harvested forest

Appendix G



- The majority of below-ground release occurs over the first five years followed by a much slower release over the next 15 years; and
- Forgone sequestration occurs over the entire project period.

Figure I-3. Representative Land Use Change Emissions Profile

Calculating the carbon intensity for a crop based biofuel (e.g. corn ethanol) requires that time-varying emissions be accounted for in a manner that allows meaningful comparison with the carbon intensity of a reference fuel (e.g. gasoline displaced by the biofuel) which releases greenhouse gases at a relatively constant rate over the years in which it is used. Staff chose to use a 30-year accounting timeframe for the LCFS in 2009 and has chosen to maintain the same one for this round of analysis. Additional details of time accounting and considerations for the 30-year selection is provided in Attachment 3.

Averaging of carbon emissions over a 30-year timeframe has been used in the carbon emissions factor model. The AEZ-EF model documentation is available in Attachment 2. This document details all the sources of data, methodologies used to estimate carbon release, assumptions, etc. used in developing this model. The current version of the AEZ-EF spreadsheet model (v. 52) and documentation are available from the LCFS web site at http://www.arb.ca.gov/fuels/lcfs/lcfs.htm.

(f) Integration of GTAP-BIO results with the AEZ-EF Model

Appendix H

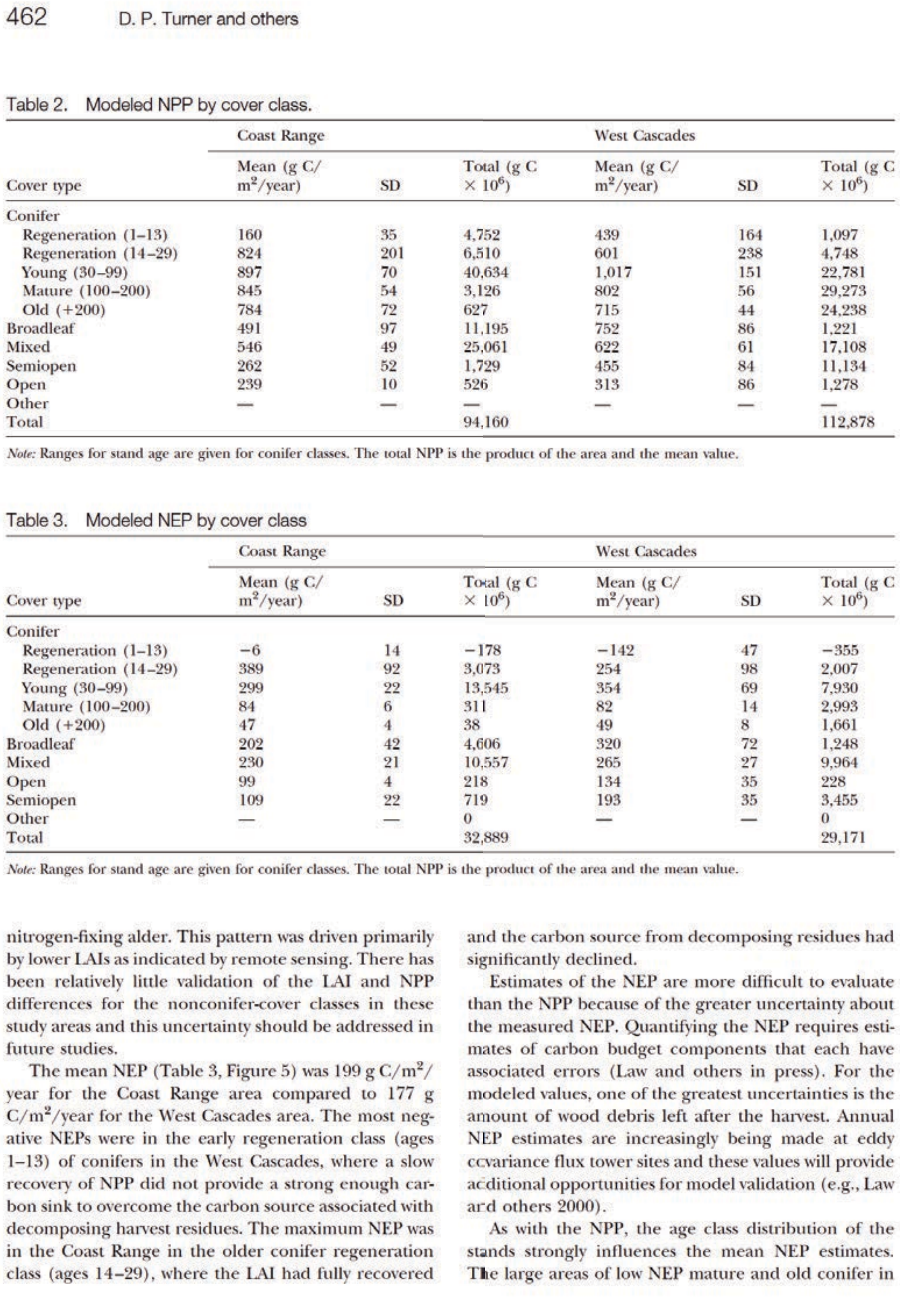


Table 2. Modeled NPP by cover class.

	Coast Range			West Cascades		
Cover type	Mean (g C/m^2/year)	SD	Total (g C $\times 10^6$)	Mean (g C/m^2/year)	SD	Total (g C $\times 10^6$)
Conifer						
Regeneration (1–13)	160	35	4,752	439	164	1,097
Regeneration (14–29)	824	201	6,510	601	238	4,748
Young (30–99)	897	70	40,634	1,017	151	22,781
Mature (100–200)	845	54	3,126	802	56	29,273
Old (+200)	784	72	627	715	44	24,238
Broadleaf	491	97	11,195	752	86	1,221
Mixed	546	49	25,061	622	61	17,108
Semiopen	262	52	1,729	455	84	11,134
Open	239	10	526	313	86	1,278
Other	—	—	—	—	—	—
Total			94,160			112,878

Note: Ranges for stand age are given for conifer classes. The total NPP is the product of the area and the mean value.

Table 3. Modeled NEP by cover class

	Coast Range			West Cascades		
Cover type	Mean (g C/m^2/year)	SD	Total (g C $\times 10^6$)	Mean (g C/m^2/year)	SD	Total (g C $\times 10^6$)
Conifer						
Regeneration (1–13)	−6	14	−178	−142	47	−355
Regeneration (14–29)	389	92	3,073	254	98	2,007
Young (30–99)	299	22	13,545	354	69	7,930
Mature (100–200)	84	6	311	82	14	2,993
Old (+200)	47	4	38	49	8	1,661
Broadleaf	202	42	4,606	320	72	1,248
Mixed	230	21	10,557	265	27	9,964
Open	99	4	218	134	35	228
Semiopen	109	22	719	193	35	3,455
Other	—	—	0	—	—	0
Total			32,889			29,171

Note: Ranges for stand age are given for conifer classes. The total NPP is the product of the area and the mean value.

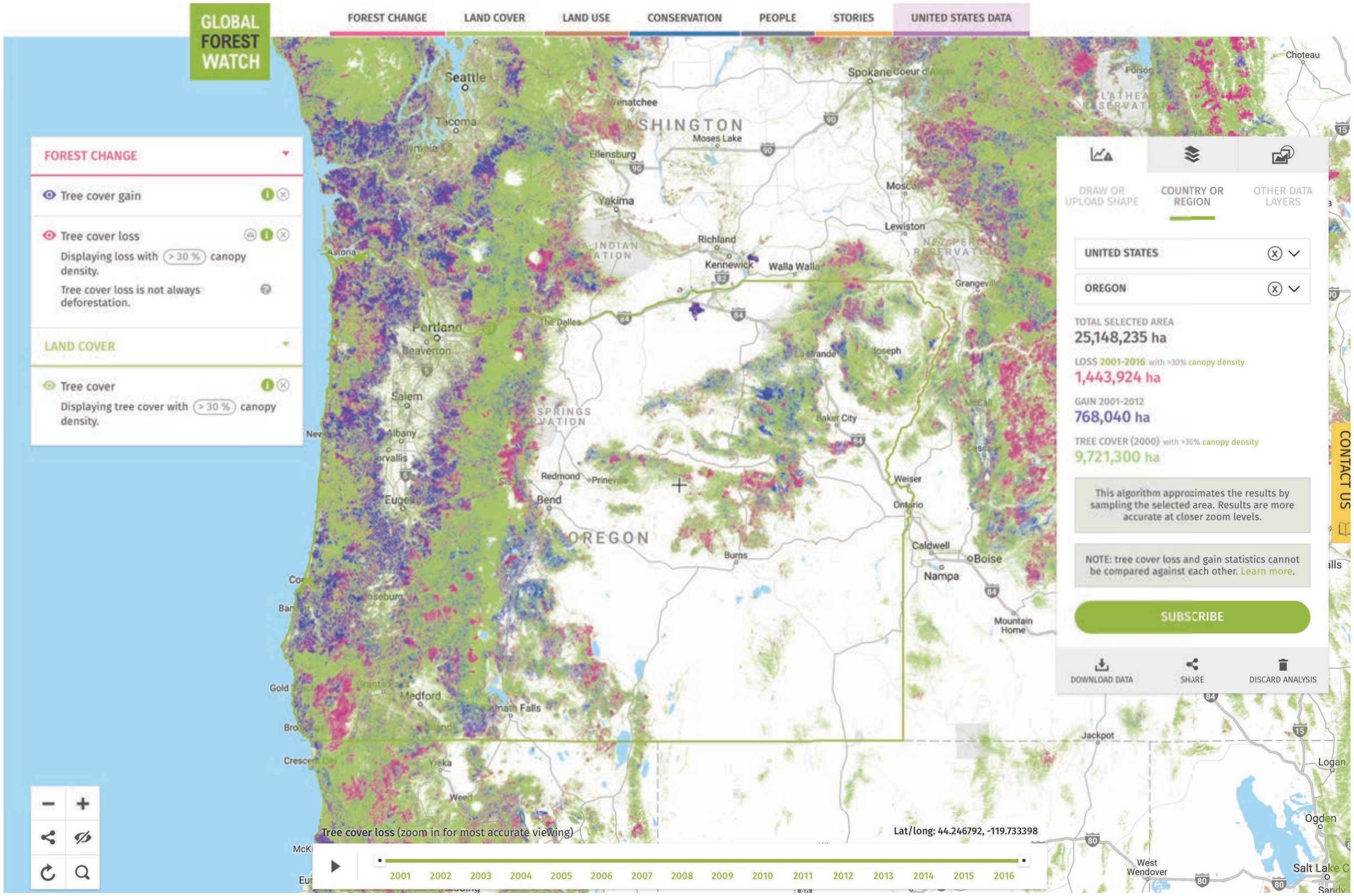
nitrogen-fixing alder. This pattern was driven primarily by lower LAIs as indicated by remote sensing. There has been relatively little validation of the LAI and NPP differences for the nonconifer-cover classes in these study areas and this uncertainty should be addressed in future studies.

The mean NEP (Table 3, Figure 5) was 199 g C/m^2/year for the Coast Range area compared to 177 g C/m^2/year for the West Cascades area. The most negative NEPs were in the early regeneration class (ages 1–13) of conifers in the West Cascades, where a slow recovery of NPP did not provide a strong enough carbon sink to overcome the carbon source associated with decomposing harvest residues. The maximum NEP was in the Coast Range in the older conifer regeneration class (ages 14–29), where the LAI had fully recovered and the carbon source from decomposing residues had significantly declined.

Estimates of the NEP are more difficult to evaluate than the NPP because of the greater uncertainty about the measured NEP. Quantifying the NEP requires estimates of carbon budget components that each have associated errors (Law and others in press). For the modeled values, one of the greatest uncertainties is the amount of wood debris left after the harvest. Annual NEP estimates are increasingly being made at eddy covariance flux tower sites and these values will provide additional opportunities for model validation (e.g., Law and others 2000).

As with the NPP, the age class distribution of the stands strongly influences the mean NEP estimates. The large areas of low NEP mature and old conifer in

Appendix I



FOREST CHANGE

Tree cover gain

Tree cover loss

Displaying loss with > 30 % canopy density.

Tree cover loss is not always deforestation.

LAND COVER

Tree cover

Displaying tree cover with > 30 % canopy density.

UNITED STATES

OREGON

TOTAL SELECTED AREA
25,148,235 ha

LOSS 2001-2016 with >30% canopy density
1,443,924 ha

GAIN 2001-2012
768,040 ha

TREE COVER (2000) with >30% canopy density
9,721,300 ha

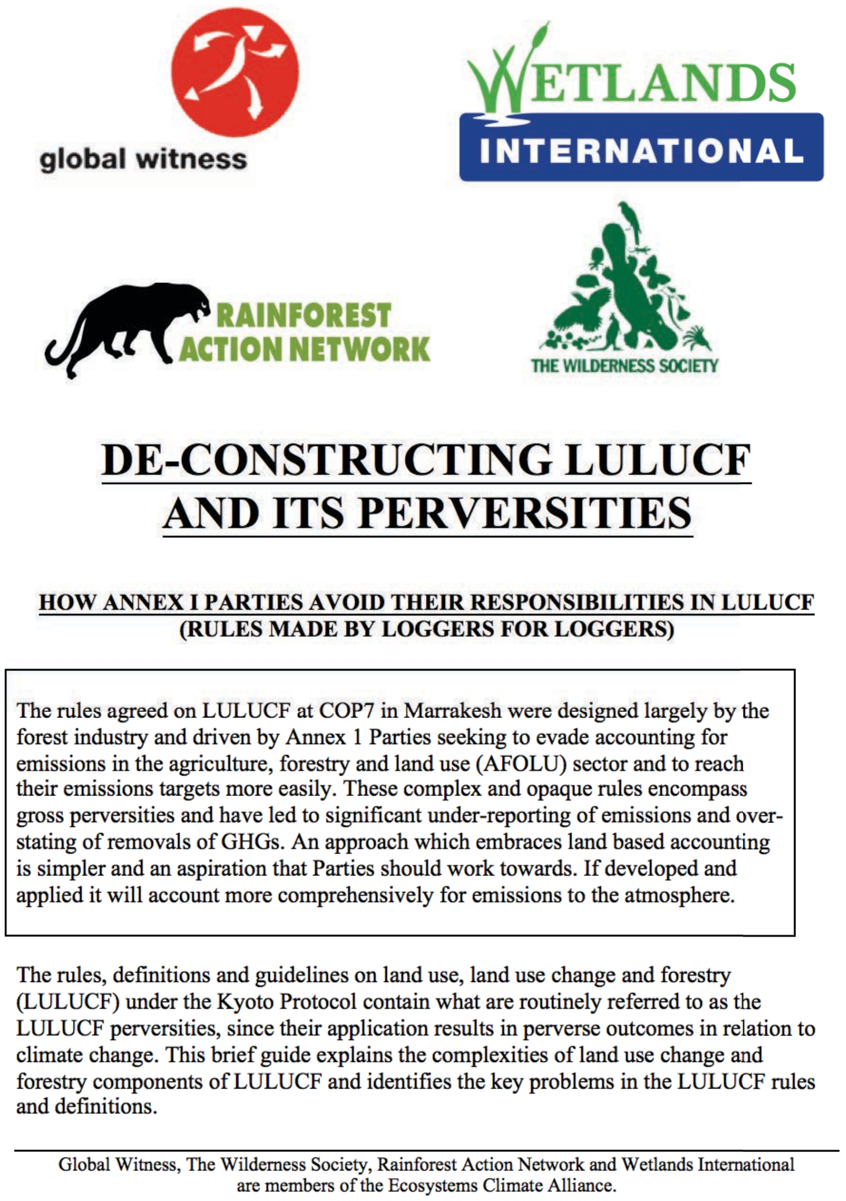
This algorithm approximates the results by sampling the selected area. Results are more accurate at closer zoom levels.

NOTE: tree cover loss and gain statistics cannot be compared against each other. Learn more.

Tree cover loss (zoom in for most accurate viewing)

Lat/long: 44.246792, -119.733398

Appendix J



DE-CONSTRUCTING LULUCF AND ITS PERVERSITIES

HOW ANNEX I PARTIES AVOID THEIR RESPONSIBILITIES IN LULUCF (RULES MADE BY LOGGERS FOR LOGGERS)

The rules agreed on LULUCF at COP7 in Marrakesh were designed largely by the forest industry and driven by Annex 1 Parties seeking to evade accounting for emissions in the agriculture, forestry and land use (AFOLU) sector and to reach their emissions targets more easily. These complex and opaque rules encompass gross perversities and have led to significant under-reporting of emissions and over-stating of removals of GHGs. An approach which embraces land based accounting is simpler and an aspiration that Parties should work towards. If developed and applied it will account more comprehensively for emissions to the atmosphere.

The rules, definitions and guidelines on land use, land use change and forestry (LULUCF) under the Kyoto Protocol contain what are routinely referred to as the LULUCF perversities, since their application results in perverse outcomes in relation to climate change. This brief guide explains the complexities of land use change and forestry components of LULUCF and identifies the key problems in the LULUCF rules and definitions.

Global Witness, The Wilderness Society, Rainforest Action Network and Wetlands International are members of the Ecosystems Climate Alliance.

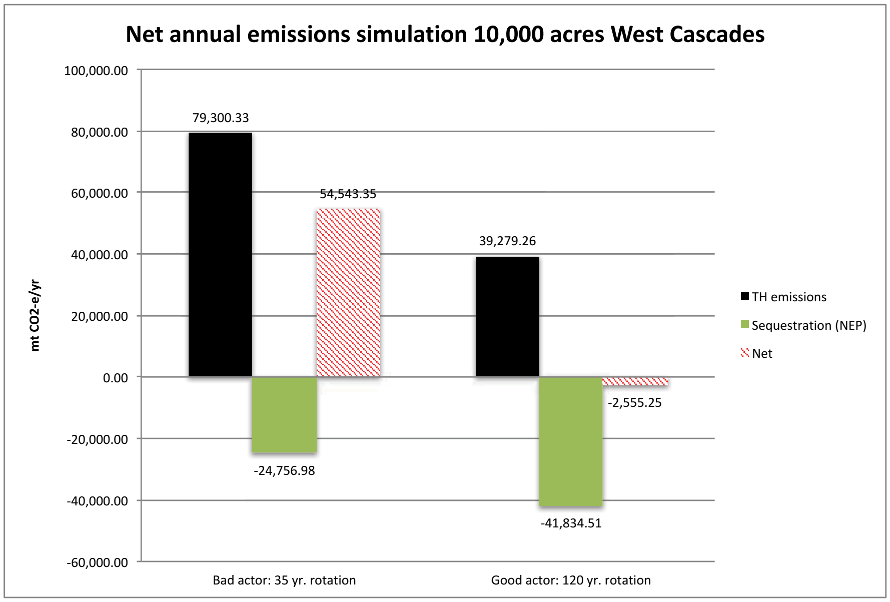
Appendix K

Good actor bad actor bar chart - West Cascades

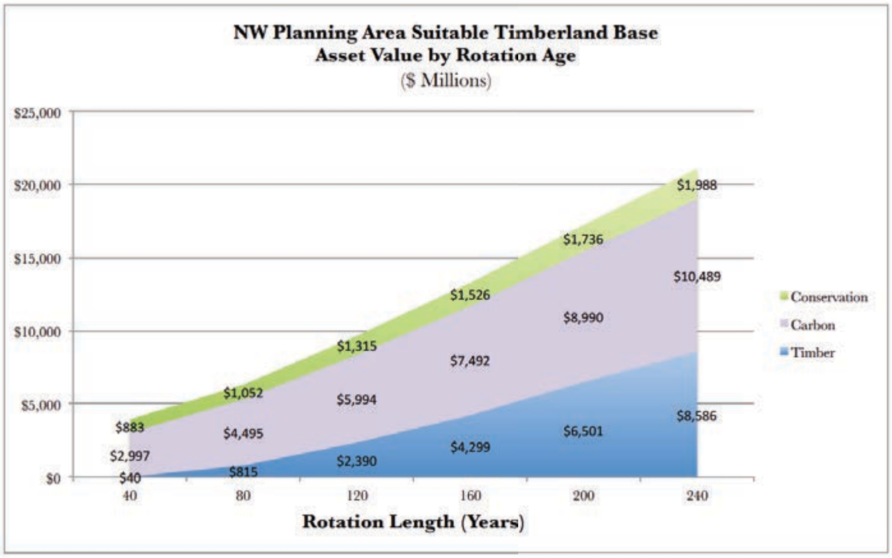
	TH emissions	Sequestration (NEP)	Net
Bad actor: 35 yr. rotation	79,300.33	-24,756.98	54,543.35
Good actor: 120 yr. rotation	39,279.26	-41,834.51	-2,555.25

	Bad actor	Good actor
Ownership size	10,000.00	10,000.00
Rotation	35.00	120.00
Embodied emissions/mbf	6.46	6.46
Mean mbf/acre	40.00	80.00
Annual acres cut	285.71	83.33
TH emissions	55,371.43	32,300.00
Acres in 0-13 at one time	4,000.00	1,166.67
FS charge	19,528.90	5,695.93
DR charge	4,400.00	1,283.33
Total annual emissions	79,300.33	39,279.26
Acres 14-29 at one time	4,571.43	1,333.33
Acres 30-99 at one time	1,428.57	7,000.00
Total annual sequestration	-24,756.98	-41,834.51
Net	54,543.35	-2,555.25

West Cascades NEP	
0-13 gC/m2/yr	-142
0-13 tCO2-e/ac/yr	-2.11
14-29 gC/m2/yr	254
14-29 tCO2-e/ac/yr	3.77
30-99 gC/m2/yr	354
30-99 tCO2-e/ac/yr	5.26



Appendix L



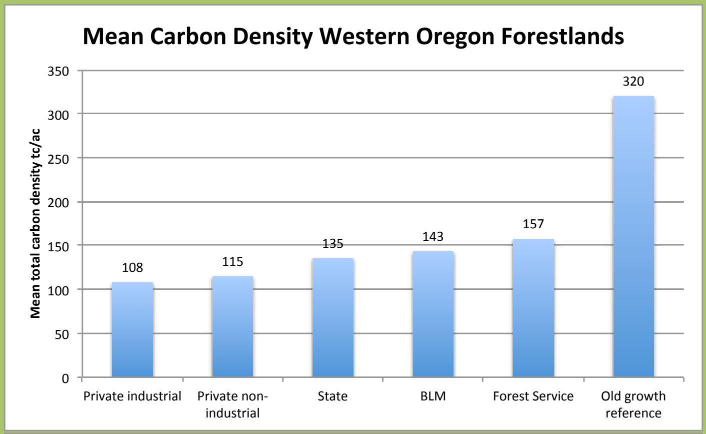
Key assumptions:

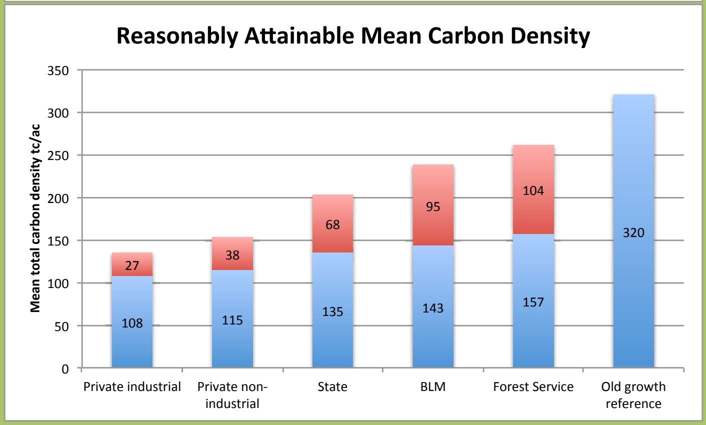
- Conservation values from historical land purchase agreements. Values represent roughly 10 times ODR's 2015 bare land specially assessed forestland values and range from $2,830 per acre for young stands to $10,410 for late successional/old growth forest.
- Carbon density in metric tons carbon per acre increases from 60 to 360 based on data from Woods Hole Institute and the USDA Forest Inventory and Analysis. Following BLM, stock is valued at the current $40/mt CO2-e social cost of carbon dioxide emissions.
- Stumpage values per million board feet increase across five product types: poles and pulpwood, small sawtimber, median sawtimber, large sawtimber, and prime veneer logs. Stumpage range of $300-$378 per MBF taken from Forest Service research and ODF bid sheets.
- Mean annual increment (MAI) figures taken from Wigg (1989). MAI by age group is as follows: 0-39 (21.1 bf/acre), 40-79 (254), 80-119 (424.1), 120-159 (459.4), 160-199 (489.1), 200-239 (453.9).

1 | Center for Sustainable Economy: draft GPV modeling results

Appendix M

Scaling Up Forest Carbon Storage


Mean Carbon Density Western Oregon Forestlands


Reasonably Attainable Mean Carbon Density

One hypothetical scenario and its effects:

- ✓ Increase mean carbon density by 25% on private industrial lands, 33% on non-industrial lands, 50% on state lands, and 66% on federal lands.
- ✓ The resulting increase in storage would top 3 billion metric tons CO2-e.
- ✓ This is equivalent to 50 years of Oregon's currently reported emissions.
- ✓ This is equivalent to the annual emissions from 871 coal fired plants

Appendix N

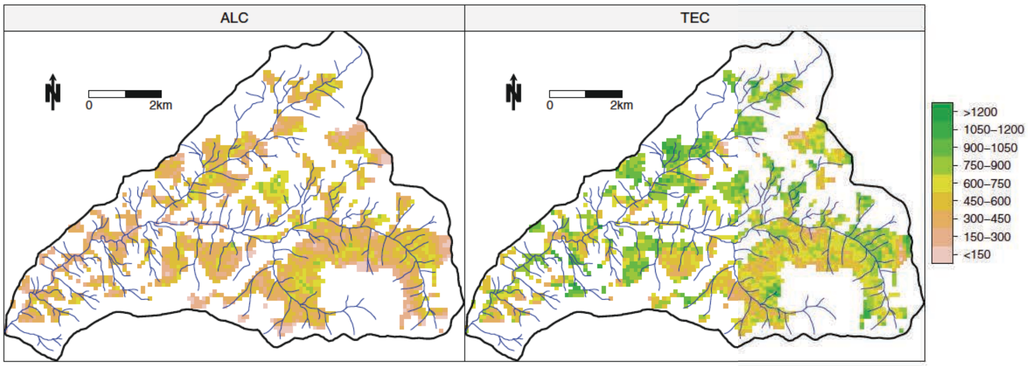


Figure 3. Aboveground live carbon (ALC, derived from Lidar) and total ecosystem carbon (TEC, simulated with iLand) in old-growth forests at the HJ Andrews Experimental Forest (Mg C ha^{-1}). (Color figure online)

Table 3. Carbon Storage in Old-Growth Forests of the HJ Andrews Experimental Forest

		ALC (Lidar)	ALC (iLand)	TEC (iLand)
Central tendency	Mean (Mg C ha^{-1})	435.1	396.5	724.5
Variation (Spatially non-explicit)	R_{90}^{1} (Mg C ha^{-1})	496.7	428.2	583.5
	CV^2 (%)	34.3	34.9	26.2
Variation (Spatially explicit)^3	Patch density^4 (100 ha^{-1})	22.1	18.1	26.5
	Division index^5 (dim.)	0.995	0.981	0.995

ALC = aboveground live carbon; TEC = total ecosystem carbon.

[1] *90th percentile range (that is, the range between the 5th and 95th percentile of landscape C density).*

[2] *Coefficient of variation.*

[3] *Results were grouped into 150 Mg C ha^{-1} classes to identify homogeneous patches (see Figure 3).*

[4] *Number of patches per 100 ha (McGarigal and others 2002).*

[5] *The probability that two randomly chosen places in the landscape are not situated in the same undissected patch (Jaeger 2000); the minimum division index from separate calculations for all C classes is reported here.*

Drivers of Spatial Variation in C Density

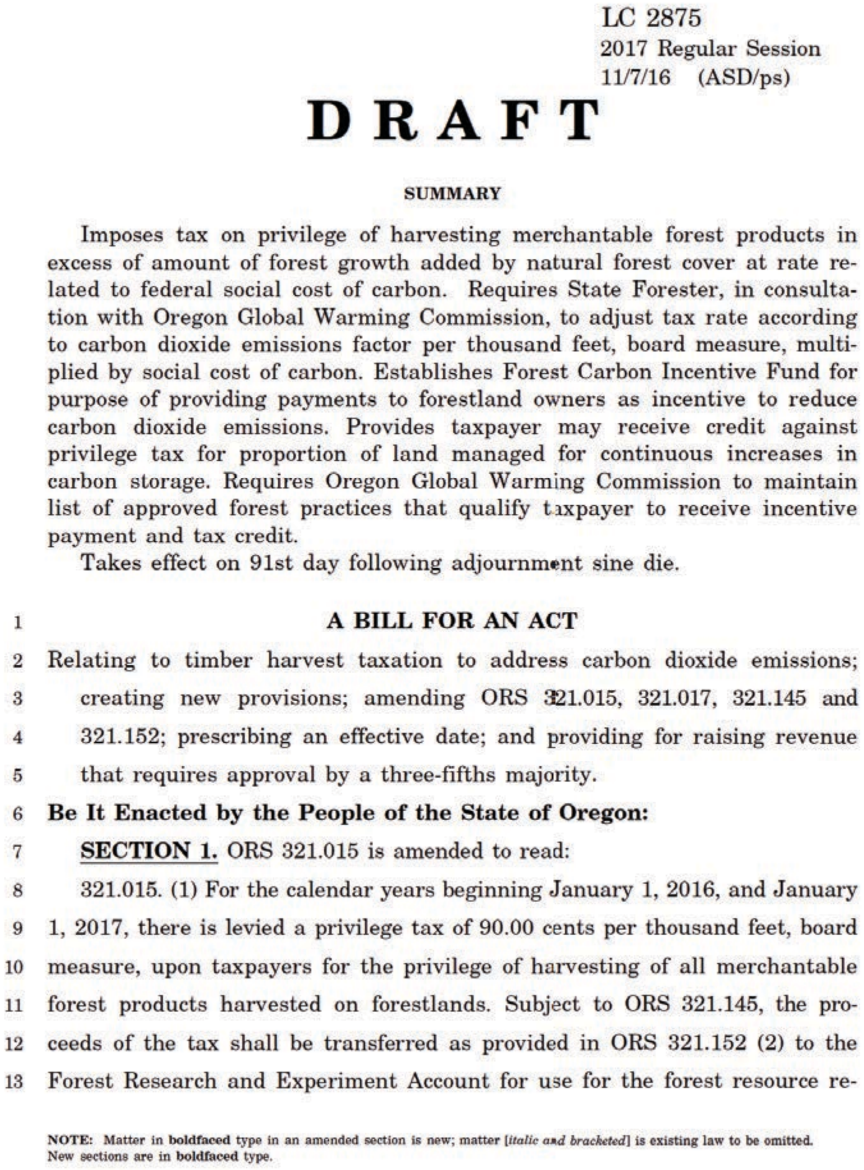
Lidar-based ALC densities were only weakly correlated with individual environmental drivers, with radiation and effective soil rooting depth being the most prominent factors (Figure 4). A stronger relationship was found with individual indicators of stand structure, with Lidar-based ALC moderately correlated to vertical and horizontal heterogeneity (that is, rumple index and SD$_{dbh}$) as well as size and stocking level (N$_{100}$ and BA). However, because of the hierarchical nature of influence (coincident effect of environment on both stand dynamics and ecosystem productivity) and the multicollinearity between individual factors these correlations allow only limited insight into the processes driving variation in C density of old-growth forests at HJA.

We thus conducted a full factorial simulation experiment with a process-based model to disentangle environmental effects from the influence of stand dynamics on C density. We found that variation in environmental drivers was responsible for 55.3% of the spatial variation in TEC density (53.8% for ALC). Radiation was identified as the most important environmental driver (Figure 5A). According to our analysis, solar energy thus had a stronger influence on C storage than climatic factors limiting plant metabolism (for example, temperature) in the mountainous terrain of HJA. Furthermore, soil physical properties (that is, the local ability to store water) were found more influential on variation in C than the overall amount of precipitation. Precipitation is generally high throughout the landscape (see Figure 1B) but is unevenly distributed over the year, with a distinct dry season in summer, which makes the ability to store precipitation and runoff from snow-melt a crucial parameter for plant growth in (solar energy-rich) early summer.

In a subsequent step, we analyzed how much of the C variation not explained by environmental

Appendix O

For the full text of this proposed legislation, please visit:
http://sustainable-economy.org/wp-content/uploads/2017/02/LC2875_DRAFT_2017_Regular_Session.pdf



LC 2875
2017 Regular Session
11/7/16 (ASD/ps)

DRAFT

SUMMARY

Imposes tax on privilege of harvesting merchantable forest products in excess of amount of forest growth added by natural forest cover at rate related to federal social cost of carbon. Requires State Forester, in consultation with Oregon Global Warming Commission, to adjust tax rate according to carbon dioxide emissions factor per thousand feet, board measure, multiplied by social cost of carbon. Establishes Forest Carbon Incentive Fund for purpose of providing payments to forestland owners as incentive to reduce carbon dioxide emissions. Provides taxpayer may receive credit against privilege tax for proportion of land managed for continuous increases in carbon storage. Requires Oregon Global Warming Commission to maintain list of approved forest practices that qualify taxpayer to receive incentive payment and tax credit.

Takes effect on 91st day following adjournment sine die.

A BILL FOR AN ACT

Relating to timber harvest taxation to address carbon dioxide emissions; creating new provisions; amending ORS 321.015, 321.017, 321.145 and 321.152; prescribing an effective date; and providing for raising revenue that requires approval by a three-fifths majority.

Be It Enacted by the People of the State of Oregon:

SECTION 1. ORS 321.015 is amended to read:

321.015. (1) For the calendar years beginning January 1, 2016, and January 1, 2017, there is levied a privilege tax of 90.00 cents per thousand feet, board measure, upon taxpayers for the privilege of harvesting of all merchantable forest products harvested on forestlands. Subject to ORS 321.145, the proceeds of the tax shall be transferred as provided in ORS 321.152 (2) to the Forest Research and Experiment Account for use for the forest resource re-

NOTE: Matter in **boldfaced** type in an amended section is new; matter [*italic and bracketed*] is existing law to be omitted. New sections are in **boldfaced** type.

Appendix P

Oregon Forest Carbon Taxable Emissions Worksheet

All values = annual averages 2000-2014

Emissions ⬛

Store/sequest 🟥

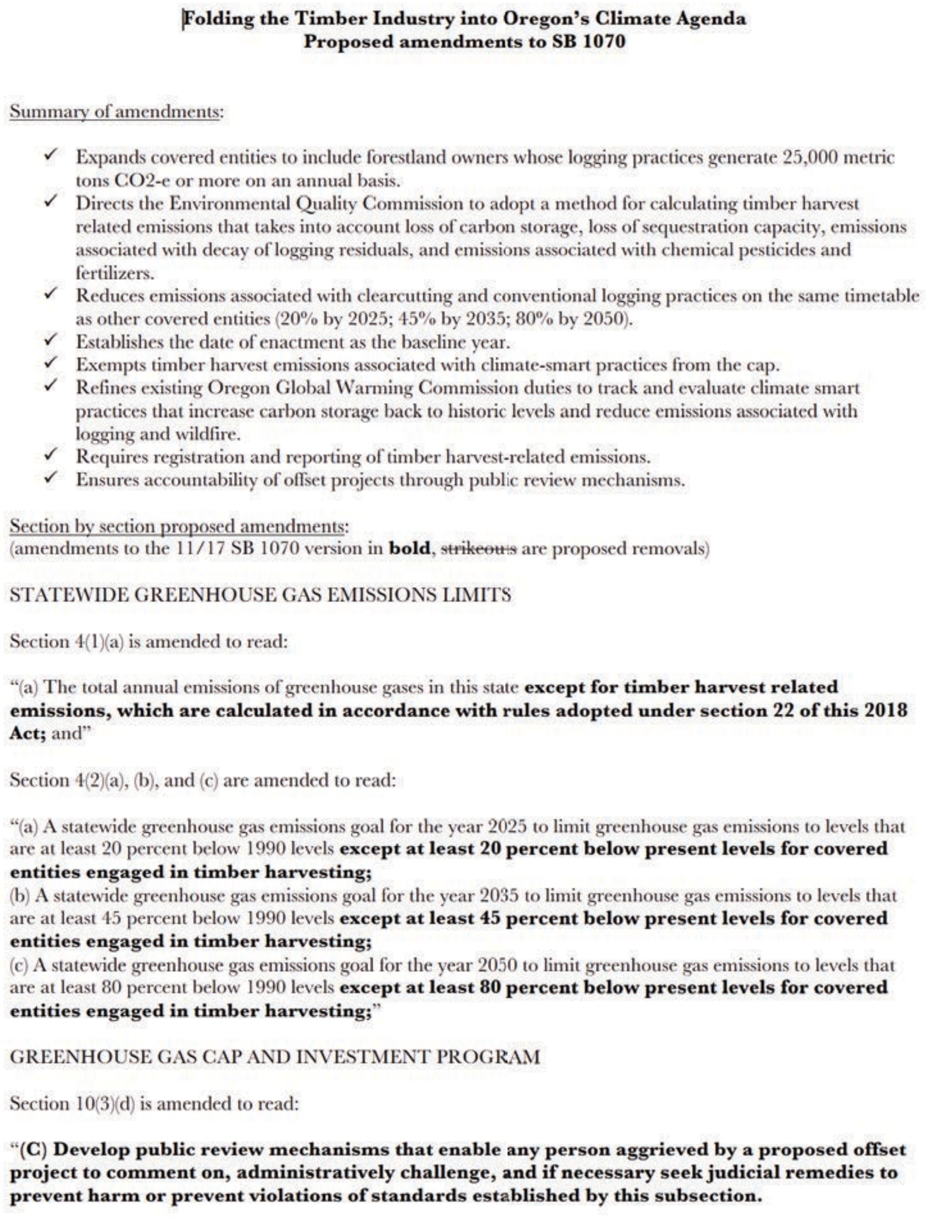
Region:	Western
Ownsership:	Pvt Industry

Emissions		
Volume timber harvest (mbf)	*2,696,467*	
Embodied CO2 factor (co2-e/mbf)	*6.46*	
Gross timber harvest emissions (MMtco2-e)		**17.41**
Share of volume to short-lived wood products	0.75	
Share of volume to long-lived wood products	0.25	
Storage in long-lived wood products (tco2-e/yr)		**4.35**
Forest cover loss	91,548	
Sacrificed sequestration factor (tco2-e/acre/yr)	4.74	
Years of loss	13	
Indirect emissions from sacrificed sequestration		**5.64**
Acreage in 0-13 age class	1,190,127	
Emissions factor 0-13 age class (NEP basis) tco2-e/ac/yr	1.11	
Direct emissions from logging residue decay		**1.32**
Pesticide and herbicide applications (kg)	9,092,570	
Pesticide and hericide emissions factor (kgCo2-e/kg)	16.43	
Fertilizer applications (kg)	6,461,538	
Fertilizer emissions factor (kgCo2-e/kg)	4.771	
Emissions from chemical and fertilizer applications		**0.18**
Total emissions (tco2-e/yr)		**20.20**
Sequestration		
Forestland acres	5,800,000	
Foresetland acres in 0-13 age class	1,190,127	
Does not meet additionality and permanence test	2,765,924	
Area occcupied by roads and infrastructure	150,000	
Natural sequestration lands	1,693,949	
Average sequestration rate (tco2-e/ac/yr)	4.74	
Sequestration on natural forestlands (tco2-e/yr)		**8.03**

		Current SCC
Taxable emissions	**12.17**	$42.42
Gross revenue ($millions) @ current SCC ($42.34/t)	**$516.28**	

Appendix Q

For the full text of these proposed amendments, please visit: https://www.oregonlegislature.gov/helm/workgroup_materials/WG%201%20-%20Public%20Comments%20from%20Sustainable%20Energy%20Economy%20Network.pdf.



Folding the Timber Industry into Oregon's Climate Agenda
Proposed amendments to SB 1070

Summary of amendments:

- ✓ Expands covered entities to include forestland owners whose logging practices generate 25,000 metric tons CO2-e or more on an annual basis.
- ✓ Directs the Environmental Quality Commission to adopt a method for calculating timber harvest related emissions that takes into account loss of carbon storage, loss of sequestration capacity, emissions associated with decay of logging residuals, and emissions associated with chemical pesticides and fertilizers.
- ✓ Reduces emissions associated with clearcutting and conventional logging practices on the same timetable as other covered entities (20% by 2025; 45% by 2035; 80% by 2050).
- ✓ Establishes the date of enactment as the baseline year.
- ✓ Exempts timber harvest emissions associated with climate-smart practices from the cap.
- ✓ Refines existing Oregon Global Warming Commission duties to track and evaluate climate smart practices that increase carbon storage back to historic levels and reduce emissions associated with logging and wildfire.
- ✓ Requires registration and reporting of timber harvest-related emissions.
- ✓ Ensures accountability of offset projects through public review mechanisms.

Section by section proposed amendments:
(amendments to the 11/17 SB 1070 version in **bold**, ~~strikeouts~~ are proposed removals)

STATEWIDE GREENHOUSE GAS EMISSIONS LIMITS

Section 4(1)(a) is amended to read:

"(a) The total annual emissions of greenhouse gases in this state **except for timber harvest related emissions, which are calculated in accordance with rules adopted under section 22 of this 2018 Act;** and"

Section 4(2)(a), (b), and (c) are amended to read:

"(a) A statewide greenhouse gas emissions goal for the year 2025 to limit greenhouse gas emissions to levels that are at least 20 percent below 1990 levels **except at least 20 percent below present levels for covered entities engaged in timber harvesting;**
(b) A statewide greenhouse gas emissions goal for the year 2035 to limit greenhouse gas emissions to levels that are at least 45 percent below 1990 levels **except at least 45 percent below present levels for covered entities engaged in timber harvesting;**
(c) A statewide greenhouse gas emissions goal for the year 2050 to limit greenhouse gas emissions to levels that are at least 80 percent below 1990 levels **except at least 80 percent below present levels for covered entities engaged in timber harvesting;**"

GREENHOUSE GAS CAP AND INVESTMENT PROGRAM

Section 10(3)(d) is amended to read:

"**(C) Develop public review mechanisms that enable any person aggrieved by a proposed offset project to comment on, administratively challenge, and if necessary seek judicial remedies to prevent harm or prevent violations of standards established by this subsection.**

Appendix R

Legislative Concept Note – 2018

Working title: Oregon Forest Resiliency Act

Purpose: Amends and revises the Oregon Forest Practices Act to require implementation of climate smart practices to enhance the resiliency of private forestlands to drought, disease, wildfire, floods, landslides, low summertime streamflow, thermal pollution, fish kills, regeneration failures and other threats associated with climate change.

Statement of the problem: Oregon's forestlands are threatened by climate change in a number of ways, all of which have the potential to be costly for forestland owners, nearby communities, for counties and the State. Even-aged industrial tree plantations managed on short rotations are at the heart of the problem because they are far more vulnerable to drought, disease, wildfire, floods, landslides, low summertime streamflow, thermal pollution, fish kills, regeneration failures and other climate change-induced impacts than natural late successional forests and riparian vegetation. The lack of native riparian vegetation along most streams also undermines climate resiliency by removing "nature's fire breaks," thereby exacerbating wildfire risk. As such, restoration of industrial tree plantations back into climate resilient landscapes in ways that maintain timber supply should be a central feature of Oregon's climate agenda.

What the bill would do:

1. Climate resiliency plans (CRPs): Requires large forestland owners (>5,000 acres) to prepare and adhere to climate resiliency plans that describe existing conditions, climate threats, and climate smart practices that will be undertaken to comply with requirements of this Act. CRPs shall be based on the best available science and subject to multi-agency review and approval. CRPs will serve as a comprehensive permit and require public participation, multi-agency review and approval.
2. Timber harvest plans (THPs). Requires large forestland owners (>5,000 acres) proposing clearcut harvest methods to file a THP for approval by the State Forester describing harvest, regeneration and resource protection measures needed to ensure the climate resiliency of future stands. THPs must also include a consistency determination with CRPs.
3. Protection and restoration of native riparian vegetation and drinking watersheds: To protect and restore native riparian vegetation and drinking water supplies, establishes water resource management areas (WRMAs) along all rivers, streams, lakes, wetlands and shorelines consistent with the best available science and the state's non-degradation policy. Designates all surface drinking water assessment areas as WRMAs. Prohibits clearcutting and chemical sprays in WRMAs. Directs the State Forester, in consultation with the Department of Environmental Quality and Department of Fish and Wildlife to develop a list of acceptable timber harvest methods within WRMAs that ensure the resiliency of water supplies and native fish and wildlife populations to climate change and enhance the role of riparian zones in mitigating wildfire threat.
4. Protection and restoration of climate resilient forests: Prohibits the conversion of any remaining natural, late successional or old growth forests into tree plantations. For entities required to prepare CRPs, requires allocation of a portion of forestlands to protect or promote the establishment of climate resilient stands of late successional and old growth forest (LSOG) through appropriate silvicultural and restoration techniques. Establishes criteria for selection of LSOG management areas. Requires delineation of such lands on maps and Department of Fish and Wildlife approval.
5. Alternatives to clearcutting and timber plantations: Provides exemptions from reforestation requirements for climate smart practices that rely on natural regeneration and leave sufficient amounts of biological legacy to maintain forest cover, protect soil and watershed conditions, and enhance long term site productivity.